

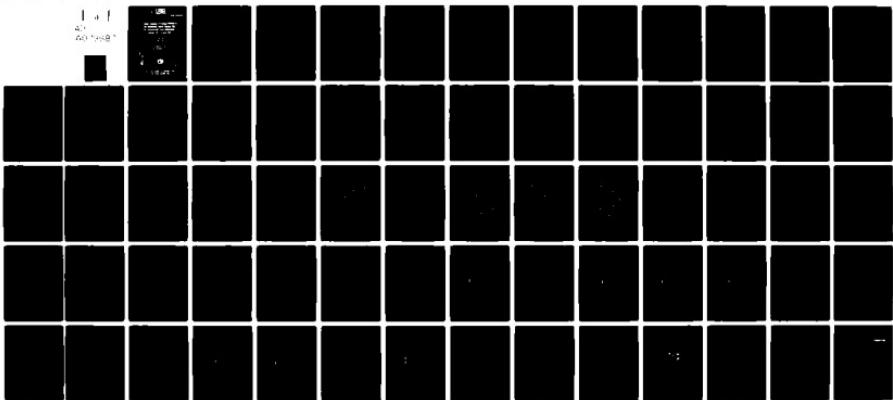
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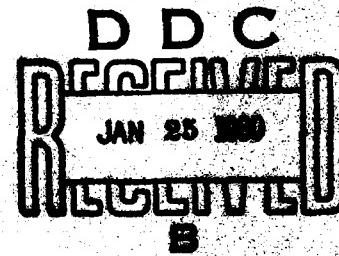
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**Ocean Dumping of Dredged Material at
the Jacksonville Harbor Improvement
An Environmental Trend Assessment
February 1977 to April 1978**

**Brinda J. Little
David K. Young**

**Oceanography Division
Naval Oceanographic Laboratory**

June 1978



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EXECUTIVE SUMMARY

The Biological and Chemical Oceanography Branch of the Naval Ocean Research and Development Activity conducted a three-phase study to assess the environmental effects of depositing 2,907,750 cubic yards of dredged material at the Jacksonville Harbor ocean disposal site designated for such purposes by the U. S. Environmental Protection Agency. Approximately 56% (1,637,000 cubic yards) of this material was dredged from the U. S. Naval Station, Mayport, Florida. The distribution of dredged material at the disposal site was found to be both vertically and horizontally heterogeneous.

Changes in bottom topography, coupled with significant increases of certain heavy metals (Ni, Cu, Pb, Zn, and Cr) within the disposal site, can be attributed to the accumulation of dredged material during the period of investigation. A standard elutriate test indicated that heavy metals were bound to the Mayport dredged material and would not be readily released to the water column during disposal operations.

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ACKNOWLEDGEMENTS

The authors particularly acknowledge Ms. C. Gordon, formerly with Naval Ocean Research and Development Activity (NORDA) Code 334, for her contributions made at sea, in the laboratory, and in data reduction and analysis. The planning and execution of field support provided by Mr. R. Guthrie, U.S. Naval Oceanographic Office (NAVOCEANO) Code 3711, were critical to the success of the field operations. We also thank Mr. L. Banchero, NORDA Code 331; Mr. D. Reid, NORDA Code 334; Dr. M. Richardson, NORDA Code 334; and Mr. J. Turcotte, NAVOCEANO Code 3421, for field support. We appreciate the assistance of Ms. I. DePalma and Ms. C. Turner of NORDA Code 334 in the laboratory. Cdr. W. H. Biggs, Head of Port Services, Mayport Naval Station, coordinated and provided ship support. Chief Eardley and crew of Tug #6 provided a safe and efficient platform for sample collection. Ens. Mike Lyon et al. provided diving support and core collections. Dr. H. Tai, Director of the Environmental Protection Agency Pesticide Monitoring Laboratory at NSTL, made available analytical equipment and technical expertise. Mr. P. J. Hannan, Ocean Sciences Division, Naval Research Laboratory, performed and interpreted the algae bioassay. Mr. C. Ashton, Jacksonville District, U. S. Army Corps of Engineers, was responsible for the placement of the marker buoy and provided information on the Jacksonville Harbor ocean disposal site.

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I. INTRODUCTION

The Biological and Chemical Oceanography Branch of the Naval Ocean Research and Development Activity (NORDA) conducted a three-phase study to assess environmental effects of disposal of 2,907,750 cubic yards of dredged material at the Jacksonville Harbor ocean disposal site designated for such purposes by the U.S. Environmental Protection Agency (EPA). The original intent of the study was the determination of environmental changes at the disposal site directly attributable to the disposal of an estimated 1,637,000 cubic yards of material dredged from the Naval Station, Mayport, Florida, from March 1977 to February 1978. During this same period of time, however, 1,270,750 cubic yards of dredged material from the lower St. Johns River (as recorded by the Jacksonville District of the U.S. Army Corps of Engineers) was also deposited at the Jacksonville Harbor disposal site. This report will summarize the results of four sample collections taken during the three phases of the U.S. Naval Station dredging operation and will provide an environmental trend assessment at the Jacksonville Harbor ocean disposal site with regard to selected sedimentary properties from February 1977 to April 1978 as a result of all disposal activities during that period.

The U. S. Naval Station at Mayport, Florida, is an actively utilized port facility on the east coast of the United States that requires periodic dredging of the harbor and its channels. The dredged material is deposited at the Jacksonville Harbor ocean disposal site, a one-square-mile area centered on 30°21.00'N, 81°18.00'W, located 7 miles southeast of the entrance to the St. John's River. The disposal site had not been marked during past dredging operations, therefore, operators of hopper dredges had to rely on radar or visual sightings to determine the location of the EPA designated area. In a 1972-73 (U. S. Naval Oceanographic Office, 1973) investigation, Navy oceanographers found that the majority of dredged material had been deposited outside the designated disposal site, thereby requiring an extensive search for the disposed material by random sampling. In an attempt to alleviate this problem for the present study, a permanent marker buoy was moored and maintained at the disposal site (30°21.16'N; 81°18.01'W) by the U. S. Coast Guard (Fig. 1). The maintenance dredging of the turning basin began March 1977 and concluded February 1978.

Sediment samples were collected in February 1977, before the dredging was initiated to obtain a pre-disposal survey; in September and December 1977, during the disposal of dredged material; and in April 1978, after dredging was completed. The purpose of the second sampling in September 1977 was to determine vertical distribution of dredged material from the sediment surface to a depth of 30 cm. The third sample collection in December 1977 was designed to determine horizontal distribution and spatial variability of dredged materials within and adjacent to the disposal site. The fourth sampling in April 1978 was intended to provide final data for the environmental trend assessment encompassing the period of time of dredging material from Mayport Harbor and disposal of this material at the Jacksonville Harbor ocean disposal site.

The results of the pre-disposal survey were presented in the first interim report (Little *et al.*, 1977) to the Naval Facilities Engineering Command (NAVFACENGCOM). The second interim report (Little *et al.*, 1978) to NAVFACENGCOM was limited to data obtained from the two sample collections, during the dredging and disposal operation. Results from the post-disposal collection were submitted to NAVFACENGCOM as the final report (Little and Young, 1978) for this project.

This assessment is limited to sedimentary properties as follows:

- (1) Grain Size
- (2) Calcium Carbonate
- (3) Total Phosphorus
- (4) Kjeldahl Nitrogen
- (5) Chemical Oxygen Demand
- (6) Volatile Solids
- (7) Oil and Grease
- (8) Organic Carbon
- (9) Heavy Metals
 - (a) Mercury (Hg)
 - (b) Arsenic (As)
 - (c) Lead (Pb)
 - (d) Zinc (Zn)
 - (e) Copper (Cu)
 - (f) Chromium (Cr)
 - (g) Cadmium (Cd)
 - (h) Nickel (Ni)

All analyses were performed using EPA approved methods and procedures described in this text. Sampling and analytical procedures, where appropriate, conform to the EPA "Proposed Revision of Regulations and Criteria" on ocean dumping (Federal Register, 1976).

In addition to these analyses, detailed bathymetric surveys were made of the disposal site to determine changes in bottom topography from February 1977 to April 1978. A standard elutriate test and a bioassay were also performed using dredged material taken from the turning basin during the pre-disposal survey.

In order to demonstrate our rationale for alterations in sampling design and additions or deletions in analyses performed in this study, each of the three sampling periods is discussed separately in the Methods and Materials and Results and Discussion sections. A final Conclusions section encompasses all sampling periods (pre-disposal, during-disposal and post-disposal) and provides a basis for temporal comparisons.

II. PRE-DISPOSAL SURVEY (FEBRUARY 1977)

A. METHODS AND MATERIALS

A detailed bathymetric survey was made of the dredged material disposal site during the pre-disposal survey, 1-3 February 1977, using a high-resolution seismic profiling system (Raytheon 723 recorder and 200 kHz acoustic transducer). Navigation was accomplished with a Cubic Autotape Model DM-40 system which has an accuracy of ± 1 m in the range/range mode.

Seventy-two sediment samples were collected. Five replicate grab samples were taken at each of nine sample stations within the disposal site and at four control stations outside the disposal site. Single grabs were taken at five stations in the Mayport Naval Station turning basin and two in the channel. These samples from the turning basin and channel were considered to be representative of the material to be dredged. Figure 2 shows the location of sample stations and control stations in relation to the disposal site.

Samples were collected using a Teflon-coated Shipek grab sampler. The sampler penetrates the bottom to a maximum depth of 10 cm and collects a sample 1/25 meter square and about 3 liters in volume. Sediment from each sample was visually described, homogenized, and divided into four subsamples for the analysis of (1) heavy metals, (2) oil and grease, (3) total phosphorus and chemical oxygen demand, and (4) grain size, volatile solids, calcium carbonate, organic carbon and Kjeldahl nitrogen. Subsamples were placed into plastic-lined cardboard cartons, packed in dry ice and kept frozen until the various analyses were performed.

Subsamples to be analyzed for heavy metals were washed with distilled water to remove interfering salts, oven dried at 50°C, and ground in a quartz-agate mortar. Ten-gram portions were digested in 100 ml of 4M HNO₃. 0.7M HCl solution for 2 hours at 90°C. The dilute nitric hydrochloric acid mixture has little or no effect on metals bound in minerals, but removes only surface adsorbed or precipitated metals from the sediment (Oliver, 1973). Acid extracts were analyzed for nickel, copper, cadmium, lead, chromium and zinc using a Perkin-Elmer 403 atomic absorption spectrophotometer. Mercury concentrations were measured using flameless atomic absorption. All analyses were performed in triplicate. Results are reported in parts per million (ppm) based on dry sediment weight.

A one-way analysis of variance (ANOVA) was performed to determine if there were significant differences (P<0.05) among metal concentrations in sediments from the disposal site and turning basin. A Student's "t" test was performed on the two channel samples. These tests permitted comparisons of heavy metal concentrations in sediments from each of the areas when those concentrations were not statistically different. For those metals that were significantly different (P<0.05) within all areas, the five subsamples comprising the sample with the highest mean concentration within the disposal site were tested (Student's "t") against that with the lowest mean concentration from the turning basin and channel. This between-area test provided a comparison biased towards the "worst possible case" for detecting dredged materials as indicated by metal content (i.e., dredged material with relatively low heavy metal concentrations deposited at the disposal site on shelf sediments with relatively high metal concentrations).

Oil and grease in sediments, for the purpose of this study, were operationally defined as that material extracted by hexane from an acidified sample which would not be volatized during analysis. This definition included soaps, fats, waxes and petroleum oils. The procedure for this determination was gravimetric, involving the Soxhlet extraction by distilled n-hexane of an acidified subsample of sediment that was dried by desiccation with magnesium sulfate monohydrate. The solvent was removed in a flash evaporator. The subsample was dried overnight and weighed. Duplicate analyses were performed for each subsample. Oil and grease concentrations are reported in mg of dry residue per kg of dry sediment.

Volatile solids are those materials that are lost on ignition at 550°C for 20 minutes in a Muffle furnace. Values for volatile solids are expressed as mean weight percentages of triplicate analyses for each subsample.

The analytical technique for the determination of Kjeldahl nitrogen consisted of digesting each subsample in sulfuric acid, making the resultant solution alkaline, distilling off evolved ammonia into an indicator solution with a micro-Kjeldahl distillation unit and titrating out the ammonia in the distillate-indicator solution with hydrochloric acid. The mean nitrogen content from triplicate analyses is expressed as percent Kjeldahl nitrogen of the total dry subsample weight.

Calcium carbonate content was determined by taking the difference between the original weight and the final weight of each subsample of sediment after solution of the soluble carbonates in 2N HCl. Values from triplicate analyses are expressed as percent of the total weight of dry subsample.

Organic carbon was determined by analyzing in triplicate each subsample of sediment with a LECO carbon analyzer which measures the carbon dioxide evolved following combustion. Results are expressed as percent organic carbon of total dry subsample weight.

Sediment grain size was determined by the method of Folk (1974). Results are expressed as the percent of the total sample weight with the following size classes: gravel - coarser than 2 mm; sand - 2 to 0.0625 mm; silt - 0.0625 to 0.0039 mm; and clay - finer than 0.0039 mm.

Sediment samples to be analyzed for chemical oxygen demand (COD) were dried to a constant weight at 80°C. The organic and oxidizable inorganic substances in the sample were oxidized with a potassium dichromate/sulfuric acid solution. The excess dichromate was titrated with ferrous ammonium sulfate using orthophenanthroline ferrous complex (ferrain) as an indicator. Results are expressed as mg COD per g of dry sediment.

The total phosphorus content was determined using dried sediment samples that had been digested with a sulfuric acid/persulfate solution. The resulting residue was diluted and filtered. Ammonium molybdate and antimony potassium tartrate were added to form an antimony-phosphomolybdate complex that was then reduced by ascorbic acid to form an intensely blue-colored complex. The color development was proportional to the phosphorus content. Results are expressed in mg of total phosphorus per g of dry sediment.

The standard elutriate test was performed in accordance with EPA criteria (Federal Register, 1976). Surface water samples were collected from both the dredging site and the disposal site in plastic bottles and stored at 4°C. Sediment

samples from the turning basin were taken with a Shipek grab sampler, placed in plastic containers and stored at 4°C. All collection bottles, bags, glassware, filtration equipment and filters were washed with 10% HCl and then rinsed three times with deionized water before use. Sediments taken from the turning basin were mixed with disposal site water in a volumetric sediment-to-water ratio of 1:4 at room temperature ($22 \pm 2^{\circ}\text{C}$) in a graduated Erlenmeyer flask. The flask was stoppered with a polyfilm-covered rubber stopper and shaken for 30 minutes on an automatic shaker at 100 excursions per minute. After mixing, the suspension was allowed to settle for one hour; the supernatant was decanted into centrifuge tubes and centrifuged at 2,000 rpm for 45 minutes. The elutriate was then filtered through a $0.45 \mu\text{m}$ membrane filter discarding the first 100 ml. The same process was repeated using dredging site water. The final solutions (standard elutriates) were stored in the dark at 4°C for three days before the analyses were made. All elutriates were prepared in triplicate.

Concentrations of nickel, copper, chromium, zinc, cadmium and lead were determined for the elutriates, disposal and dredging site waters using a Perkin-Elmer 403 atomic absorption spectrophotometer. The pH of water samples from the disposal site, the dredging site and the elutriates were measured with a Corning pH meter (model 130, accuracy ± 0.01 pH units).

A bioassay using elutriates of the Mayport dredged material and the alga Phaeodactylum tricornutum was performed by P. J. Hannan of the Naval Research Laboratory, Washington, D. C., according to the procedures of Hannan and Patouillet (1979). The alga was harvested from a growing culture and the cells were washed three times with 3.5% NaCl. After having been resuspended in the salt water to form a dense slurry, the chlorophyll content was determined. Portions of the slurry were then added to the test suspensions to give a final inoculum of $0.005 \mu\text{g}$ chlorophyll/ml. This value corresponds roughly to a suspension density of 3 parts per million by volume or approximately 10,000 cells/ml. Each test included the following 500 ml volume cultures: (1) controls; (2) standard toxicant - 0.0033 ppm Hg; (3) elutriate of the dredge material (50 ml sediment mixed with 950 ml seawater for 1/2 hour, then filtered); and (4) diluted elutriate (half concentration of 3 above). The compositions of suspensions for each test are shown in Table 1.

TABLE 1
COMPOSITIONS OF SUSPENSIONS USED IN ELUTRIATE TESTS

<u>Suspension</u>	<u>Elutriate (ml)</u>	<u>Seawater (ml)</u>	<u>Culture Medium (ml)</u>
1. Control	0	458	42
2. Standard toxicant	0	458+Hg	42
3. Elutriate	458	0	42
4. Diluted elutriate	229	229	42

The cultures were illuminated with 40W fluorescent bulbs at an intensity of 250 foot-candles. The temperature was maintained at $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$. Growth rate was estimated as increases of chlorophyll "a" per unit time. Fluorescence measurements were made at 20 and 44 hrs by the method of Slovacek and Hannan (1977).

B. RESULTS AND DISCUSSION

Figure 3 shows the results of the bathymetric survey of the disposal site. The data were plotted and contoured at one-foot intervals.

Figure 4 graphically shows the concentrations in ppm of heavy metals - nickel, zinc, copper, lead, chromium and cadmium (arranged in order of increasing upper limits of standard deviation) in samples taken from the disposal site (samples 1-13), the channel (C_1 and C_2) and turning basin (T_1-T_4). Significantly different ($P < 0.05$) metal concentrations between disposal site stations were found for all metals with the exception of copper and cadmium. High within-sample (i.e., between-replicate) variance for any given analysis of sediment from each station at the disposal site indicated that there was a great amount of spatial heterogeneity of sediments at each station. This result was predictable from observations of the differing compositions of the five replicate grabs from each station. Some contained streaks of dredged material, others contained clean shell hash, while others had intact "boluses" of dredged material on top of sand.

There were significant differences ($P < 0.05$) in the levels of concentrations of all metals in samples from the turning basin. A t-test showed no significant differences ($P > 0.05$) in concentrations of chromium and cadmium between the channel stations. Cadmium was the only metal shown to be homogeneously distributed in both the disposal site and the channel, but not in the turning basin. Therefore, no further ANOVA's were run for areal comparisons.

A t-test was performed on the sample with the lowest mean concentration of each metal in the turning basin and that with the highest mean concentration of the same metal in the disposal site. For every metal analyzed, the disposal site was significantly lower ($P < 0.05$) in metal concentrations than the turning basin.

Figures 5-10 show the distribution of heavy metal concentrations at the disposal site. The highest concentrations of nickel, lead and chromium were localized in the same area - stations 1, 2 and 3. This same area had the highest proportion of silt and clay (Fig. 11). Mercury was present in concentrations at or below detection limits in sediments from all sites sampled, therefore, this analysis was deleted.

Heavy metal concentrations in standard elutriates of Mayport dredged material are presented in Table 2. Results are given as averages of triplicate elutriates. Chromium concentrations were below detectable limits in the water samples and the elutriates. Nickel, cadmium and lead concentrations were below detection limits in the disposal site water as were those of cadmium and lead in the dredging site water. Zinc was the only heavy metal with increased concentrations in the elutriates over that in the disposal and dredging site waters. Concentrations of copper decreased in the elutriates relative to that in the disposal and dredging site waters. The pH values of the elutriates were not significantly different from those of the original water samples (range: 8.09-8.17).

TABLE 2

HEAVY METAL CONCENTRATIONS IN STANDARD
ELUTRIATES OF MAYPORT DREDGED MATERIAL

	<u>Ni</u>	<u>Cu</u>	<u>Cr</u>	<u>Zn</u>	<u>Cd</u>	<u>Pb</u>
	ppm	ppm	ppm	ppm	ppm	ppm
Disposal Site Water Elutriate	N.D.* 0.0130	0.0020 N.D.	N.D. N.D.	0.0173 0.0210	N.D. 0.0006	N.D. 0.0118
Dredging Site Water Elutriate	0.0012 0.0012	0.0007 N.D.	N.D. N.D.	0.0092 0.0130	N.D. N.D.	N.D. 0.0045

*N.D. - Below detection limits.

The intent of the elutriate test is to simulate, in part, conditions of a dredging operation and to predict effects on water quality from release of contaminants from the sediment (Federal Register, 1976). The test is operationally a measure of the kinetics and resultant forces affecting the partitioning of heavy metals between the dissolved and solid phases in a suspension. Variables that are known to affect trace metal partitioning are salinity, pH of the aqueous phase, surface area provided by suspended particles and reactivities of each heavy metal (O'Connor, 1976).

The results of the standard elutriate test can be affected by a number of variables, previously discussed, that make the interpretation of the results difficult, if not impossible. A bioassay offers a sensitive indication of the potential short-term effects of chemicals released to the water column during dredging and disposal operations. The organisms most likely to be affected by such a chemical release are small, short-lived phytoplankton and zooplankton.

In the bioassay performed using the planktonic alga Phaeodactylum tricornutum and elutriates of sediment from the Mayport turning basin, there was no inhibition of growth of the alga; indeed, there was a slight enhancement of growth. The material to be dredged from Mayport Harbor was therefore deemed not toxic to the alga. The observed promotion of growth may have been due to a release of nutrients from the sediments to the elutriate (P. J. Hannan, personal communication).

Shelf sediments collected from the area of the disposal site were predominantly sand (as high as 99%) with some shell hash and gravel; whereas samples from the turning basin contained small amounts of sand (5% - 23%) and were predominantly clay (14% - 74%) and silt (5% - 22%). Anomalously high concentrations of clay and silt in certain samples from the disposal site correlated with visual observations of dredged material in those samples.

Oil and grease concentrations in all samples analyzed (Table 3) were well below that reported from the same area in 1972 (U. S. Naval Oceanographic Office, 1973). The finding of lower concentrations of oil and grease for harbor samples in 1977 than in 1972 was confirmed by a second analysis (Di Salvo, personal communication). The prevalent use of flocculating agents that "collected" surface oils and caused them to

precipitate in the form of tar balls may have contributed to the high oil and grease values reported in the 1972 survey (U. S. Naval Oceanographic Office, 1973). That practice was discontinued shortly after the 1972 survey. There were no visible tar balls in the samples taken from the turning basin in February 1977. The variance of the oil and grease concentrations was large in all cases, indicating high within-station heterogeneity.

The mean percent weights of volatile solids (Table 3) for the turning basin samples were higher (range: 5.47% - 16.17%) than those of stations located within the disposal site (range: 0.45% - 2.28%). Highest values within the disposal site were at stations 1, 2 and 3. Channel samples showed volatile solids concentrations similar to those of the disposal site (range: 0.82% - 3.79%).

The mean percent organic carbon contents of sediments (Table 3) from the turning basin (range: 2.76% - 3.36%), with the exception of station T1, were higher than that of sediments taken from the disposal site (range: 0.03% - 0.47%). The range of organic carbon contents of the channel samples was 0.08% - 0.86%. The highest concentration of organic carbon in sediments at the disposal site was found at station 1.

The mean percent Kjeldahl nitrogen contents of samples from the turning basin were higher (range: 0.30% - 0.47%) - with the exception of station T1 (Table 3) - than those from the disposal site (range: 0.01% - 0.04%). Concentrations of Kjeldahl nitrogen were uniformly low in sediments from the disposal site. Channel samples ranged from 0.02% to 0.12% in Kjeldahl nitrogen concentrations.

The mean percent calcium carbonate concentrations of sediments from the turning basin ranged from 24.10% to 66.10%, while those of sediments from the disposal site ranged from 7.20% to 24.38% (Table 3). Channel samples ranged from 11.00% to 31.40% calcium carbonate concentrations. The high calcium carbonate concentrations in sediments from the disposal site were attributable to the presence of clumps of calcareous marl observed in the grab samples (e.g., samples from stations 2, 3, 6, 11 and 12). The prevalence of these clumps of marl at the disposal site from previously disposed dredge material obscured differences in calcium carbonate concentrations between stations due to disposal of dredged material during the period of this study; therefore, this analysis was subsequently deleted.

The ranges of percent volatile solids, percent Kjeldahl nitrogen, and percent organic carbon for the samples from the disposal site and the channel overlapped while those from the turning basin were in all cases much higher with no overlap (Fig. 12). However, values for percent calcium carbonate overlapped for all three areas (Fig. 12).

COD data, as shown graphically in Figure 13, were suspect. The drying of sediments to a constant weight oxidizes all sulfides which would dominate the COD loading in most marine sediments. Further, chloride ion, ubiquitous in saline waters and sediment pore waters, is an EPA-documented interference in the COD technique (U.S. Environmental Protection Agency, 1977). Thus, samples which appear to have identical COD values may, in fact, exhibit variable chloride ion concentrations coupled with other chemical species which would appear as COD loading. This analysis was therefore deleted for all subsequent samples in this study.

At the present time, there is no EPA approved method for the determination of total phosphorus in marine sediments. The recommended procedures are designed for the analysis of phosphorus in water. These methods "...may be applicable to sediment-type

TABLE 3

MEANS AND STANDARD DEVIATIONS OF CHEMICAL PROPERTIES OF MAYPORT SAMPLES. EACH VALUE FOR DISPOSAL SITE STATIONS IS A MEAN OF THREE REPLICATES FOR EACH OF FIVE SAMPLES; EACH VALUE FOR CHANNEL AND TURNING BASIN STATIONS IS A MEAN OF THREE REPLICATES FOR EACH SAMPLE. VALUES ARE EXPRESSED AS PERCENT OF TOTAL DRY WEIGHT.

Station	Volatile Solids	Kjeldahl Nitrogen	Calcium Carbonate	Organic Carbon	Oil & Grease			
Disposal Site	\bar{X}	S	\bar{X}	S	\bar{X}	S	\bar{X}	S
1	2.28	1.43	0.04	0.04	11.94	2.73	0.47	0.43
2	1.27	1.39	0.01	0.01	24.38	21.92	0.08	0.07
3	1.06	0.82	0.02	0.02	13.58	6.00	0.14	0.10
4	0.88	0.59	0.02	0.02	8.30	1.58	0.12	0.11
5	0.68	0.22	0.01	0.01	10.00	1.59	0.06	0.02
6	0.95	0.84	0.02	0.02	9.54	1.08	0.14	0.14
7	0.82	0.14	0.02	0.00	20.54	4.58	0.06	0.01
8	0.63	0.37	0.02	0.01	9.30	1.23	0.06	0.04
9	0.46	0.09	0.01	0.00	7.38	0.87	0.03	0.00
10	0.45	0.07	0.01	0.00	7.06	0.64	0.04	0.01
11	0.45	0.07	0.01	0.00	9.26	1.96	0.05	0.00
12	1.02	0.54	0.02	0.01	8.98	1.74	0.09	0.06
13	0.44	0.08	0.01	0.00	7.20	1.89	0.06	0.01
Channel 1								
C1	3.79	---	0.12	---	11.00	---	0.86	---
C2	0.82	---	0.02	---	31.40	---	0.08	---
Turning Basin								
T1	5.47	---	0.06	---	66.10	---	0.67	---
T2	16.17	---	0.40	---	29.70	---	3.24	---
T3	10.02	---	0.30	---	24.10	---	2.76	---
T4	15.18	---	0.42	---	28.30	---	2.89	---
T5	14.64	---	0.47	---	30.20	---	3.36	---

samples...but sufficient data is (sic) not available at this time to warrant such usage when measurements for phosphorus content are required" (U. S. Environmental Protection Agency, 1976). The results (Fig. 13) that were obtained in applying these methods to sediment samples did not reveal differences that could be attributed to the presence of dredged material. The precision between duplicates of the same subsample was often quite poor for the total phosphorus measurements. Because of these currently unresolved problems, measurements of total phosphorus were deleted from subsequent analyses.

III. DURING-DISPOSAL SURVEY (SEPTEMBER AND DECEMBER 1977)

A. METHODS AND MATERIALS

Stations 1, 2 and 3 represent locations within the disposal site whose coordinates were used for all sampling (Fig. 14). Station 1, the center of the disposal site, was marked by a permanent marker buoy. Stations 2 and 3 were north and east, respectively, of station 1. It was obvious from the results of the pre-disposal survey that these stations were representative of the disposal site.

Stations 10, 11 and 13 were selected as controls (outside the disposal site) one nautical mile west, north and south, respectively, from the center of the disposal site. It was necessary to collect control samples free of dredged material. Therefore, grab samples taken in subsequent collections were discarded if dredged material was observed and grab samples were taken at successive one-quarter mile intervals farther from the original stations until control samples of sediments visually free of dredged material were obtained (Fig. 14). In addition some indication regarding movement of dredged material was deduced from this sampling design. For example, station 13 in December was 1.5 nautical miles farther south than station 13 in September (Fig. 15). Therefore, stations 10, 11, and 13 were designated as "areal controls."

A team of SCUBA divers was used to collect samples for the second (September 1977) sampling survey. Divers also surveyed the extent of horizontal dispersion. Samples were collected by inserting 1 m lengths of 2 in (O.D.) Kullenberg core liners vertically into the sediments. Triplicate cores were taken at each station. The cores were immediately capped and quick frozen using dry ice while they were maintained in a vertical position. The frozen cores were transported to the laboratory where each was subdivided into 10 cm lengths for the first 30 cm.

A teflon-coated Shipek grab sampler was used for the third (December 1977) survey. Five replicate grab samples were taken at each station. The sediment from each sample was visually described, homogenized, divided into four subsamples and analyzed as previously described.

B. RESULTS AND DISCUSSION

1. September Sampling

Core samples were highly variable in sediment type throughout their lengths. Distinct layering of organic-rich sediments and marl with fine to coarse sands and shell hash indicated the presence of dredged material to depths as great as 75 cm in the longest core taken (station 1). This distinct layering of sediments at all stations contributed to high vertical variability in concentrations of heavy metals (Figs. 16-21), Kjeldahl nitrogen (Fig. 22), percent volatile solids (Fig. 23),

percent silt-clay (Fig. 24) and percent organic carbon (Fig. 25). Diver observations of sediment ripples within and adjacent to the disposal site suggested a hydrodynamically active zone at the sediment-water interface. Intact boluses of dredged material were observed on the sediment surface within the disposal site.

A Student's t-test was used for a comparison of metal concentrations of sediments from the grouped stations (1, 2 and 3) within the disposal site with those from the grouped stations (10, 11 and 13) outside the disposal site. The three stations inside the disposal site were significantly higher (P.05) in concentrations for all the metals analyzed, with the exception of zinc, which was not significantly different (P.05) between the two areas.

2. December Sampling

The samples collected in December were composed predominantly of sand, with the exception of one grab sample at Station 1 and one grab sample at Station 2, where clay and silt both exceeded sand content. In general, sediments from stations 1 and 2 showed a higher clay-silt to sand ratio than all other stations.

A t-test was used to compare heavy metal concentrations of sediments within the disposal site (stations 1, 2 and 3) with those outside the disposal site (stations 10, 11 and 13). There were significantly higher (P.05) concentrations of each metal inside the disposal site. A similar test showed that sediments within the disposal site also had significantly higher (P.05) concentrations of oil and grease. Data were compared for the following parameters: percent Kjeldahl nitrogen vs. percent organic carbon; percent Kjeldahl nitrogen vs. percent clay-silt; and percent organic carbon vs. percent clay-silt (Fig. 26). The resultant correlation coefficients ($r = 0.933$, 0.983 , and 0.905) showed a significant (P.05) level of correlation between each pair for each of the three comparisons.

3. Temporal Comparisons

The sampling design and collection procedures for the December 1977 sampling period were similar to those for the February 1977 pre-disposal survey, thereby permitting temporal comparisons to be made for all parameters.

A Student's t-test was used to compare the two sampling periods for percent organic carbon, percent Kjeldahl nitrogen and percent volatile solids. There were significant increases (P.05) in the concentrations of all three parameters in December relative to February. A comparison of the percent Kjeldahl nitrogen content of sediment from the stations (1, 2 and 3) within the disposal site for the February and December sampling periods was made using a t-test. A similar comparison was made for the stations (10, 11 and 13) outside the disposal site. The same procedure was completed for percent organic carbon, percent volatile solids and percent clay-silt. In all cases, the December samples showed a significantly higher (P.05) concentration for each parameter tested.

T-tests were also run on heavy metal concentrations from grab samples within the disposal site stations (1, 2 and 3) to provide a comparison by station between the February (pre-disposal) and December (during-disposal) sampling periods. The February samples had higher nickel concentrations than the December samples, with no significant difference (P.05) at station 2. The only station exhibiting a significant difference (P.05) in copper concentrations was station 2, having greater concentrations in the December samples. Lead concentrations at station 3 were

significantly greater (P.05) in December than in February. Chromium concentrations differed significantly (P.05) at stations 1 and 2, with December samples having higher concentrations than those in February. Zinc concentrations at all three disposal site stations were significantly higher (P.05) in December than in February.

A t-test was used for comparing heavy metal concentrations from stations 1, 2 and 3 of the February sampling with those from stations 1, 2 and 3 of the December sampling. Lead showed no significant (P.05) differences in concentrations between the two sampling periods. Nickel concentrations showed a significant (P.05) decrease from February to December.

IV. POST-DISPOSAL SURVEY (APRIL 1978)

A. METHODS AND MATERIALS

A detailed bathymetric survey was made of the dredged material disposal site similar to that made during the pre-disposal survey. A comparison of the bathymetry of the disposal site in April 1978 with that in February 1977 could therefore be made. Disposal site stations 1, 2 and 3 as well as areal control stations 10, 11 and 13 were selected to provide temporal comparisons with previous collections. Sample station locations within the operational disposal site were those used in previous collections (Fig. 14). Grab samples from control stations were discarded if dredged material was observed and grabs were taken at successive one-quarter mile intervals farther west, north and south, respectively, from the original stations until control sediments were visually free of dredged material. Locations of the areal control stations are indicated in Figure 15.

B. RESULTS AND DISCUSSION

A comparison of bathymetry within the disposal site during the post-disposal survey, 17-20 April 1978 (Fig. 27) with that during the pre-disposal survey, 1-3 February 1977 (Fig. 3) showed that substantial changes to bottom topography had occurred over this fifteen-month interval. The greatest change in bathymetry occurred at the center of the disposal site with shoaling to 34 feet water depth where 43 feet water depth was measured during the pre-disposal survey.

Dredged material was present in grab samples up to 5.0 nautical miles south of the center of the disposal site (Fig. 15). This dredged material was observed as loose, small boluses of organic-rich, clay-silt sized sediment often with imbedded fine to coarse sands and shell hash, suggesting that the boluses had been moved along the sediment surface as bedload material. Evidence of dredged material in grab samples from the areal control station (station 13) south of the disposal site indicated a southward movement of dredged material. Such material was not found at areal control stations (stations 10 and 11) one nautical mile to the west and north, respectively, from the center of the disposal site. Exploratory grabs taken one nautical mile east of the disposal site center showed that no dredged material was present at the sediment surface. Therefore, movement of dredged material from February 1977 to April 1978 appeared to be predominantly in a southerly direction.

A Student's t-test was used to compare concentrations of heavy metals (Cu, Ni, Pb, Cr and Zn), oil and grease, organic carbon and Kjeldahl nitrogen of sediments within the disposal site (stations 1, 2 and 3) with those outside the disposal site

(stations 10, 11 and 13). Significant differences ($P < 0.05$) were found with all parameters inside versus outside the disposal site with higher concentrations being found in sediments from within the disposal site.

A one-way ANOVA was run on metal concentrations (Pb, Zn, Cu, Cr and Ni) of sediments collected from three grouped stations (1, 2 and 3) from within the disposal site during the February 1977, December 1977 and April 1978 sampling periods. Cadmium was not tested because concentrations from all stations at all times were below 0.5 ppm. Highly significant differences ($P < 0.01$) were found with time among all metals with highest concentrations occurring in April 1978 (Fig. 28).

A one-way ANOVA was also run on metal concentrations (Pb, Zn, Cu, Cr and Ni) of sediments collected from three grouped areal control stations (10, 11 and 13) in February 1977, December 1977 and April 1978. Again, cadmium was not tested because concentrations from all stations at all times were below 0.5 ppm. Significant differences ($P < 0.05$) were found with time among all metals. Highest mean concentrations of all metals occurred in April 1978 (Fig. 29).

V. CONCLUSIONS

The U. S. Coast Guard buoy near the center of the disposal site was used as a marker for disposal of dredged materials by other users in addition to the U.S. Navy. Because of the other dredge disposal operations, a determination of the environmental impact that can be directly attributed to the disposal of dredged material from Mayport harbor was not possible. Consequently, the conclusions reported here represent an environmental trend assessment of all dredged material disposal from February 1977 until April 1978 at the Jacksonville harbor ocean disposal site.

The distribution of dredged material, both vertically and horizontally, is extremely heterogeneous at the Jacksonville Harbor ocean disposal site. The spatial heterogeneity is expressed within 10 cm of vertical scale and 1 m of horizontal scale - representing, respectively, the increment of subsampling of each diver-collected core and the spacing between replicate core samples at each station. The resultant high within-sample variability of sedimentary properties is compounded by high variability of the same properties between samples. Core samples provided evidence of distinct layering of dredged material with depth, which together with diver observations of sediment ripples, are indicative of a hydrodynamically active continental shelf environment.

Water depths at the center of the disposal site were up to 9 feet shallower in April 1978 than in February 1977. There were no discernable changes in bathymetry outside the disposal site during this period, so it can be assumed that the shoaling was due to the ocean disposal activities. Although there were no major changes in bottom topography outside of the disposal site, progressive bed-load movement of dredged material from the disposal site in a southerly direction was apparent in the September 1977, December 1977 and April 1978 sampling periods. The changes in bathymetry, coupled with significant increases of certain heavy metals (Ni, Cu, Pb, Zn and Cr) within the disposal site can be attributed to the accumulation of dredged material during the February 1977-April 1978 period. Concentrations of Kjeldahl nitrogen, organic carbon, oil and grease and silt-clay from within and outside disposal site sediments were inconsistent and showed no discernable temporal trends.

A standard elutriate test indicated that heavy metals were tightly bound to Mayport dredged material and would not be readily released to the water column during dredging and disposal operations. Elutriates of sediment from the Mayport turning basin enhanced rather than inhibited growth of the planktonic alga Phaeodactylum tricornutum, thereby suggesting non-toxic concentrations of chemical contaminants in Mayport dredged material available to phytoplankton.

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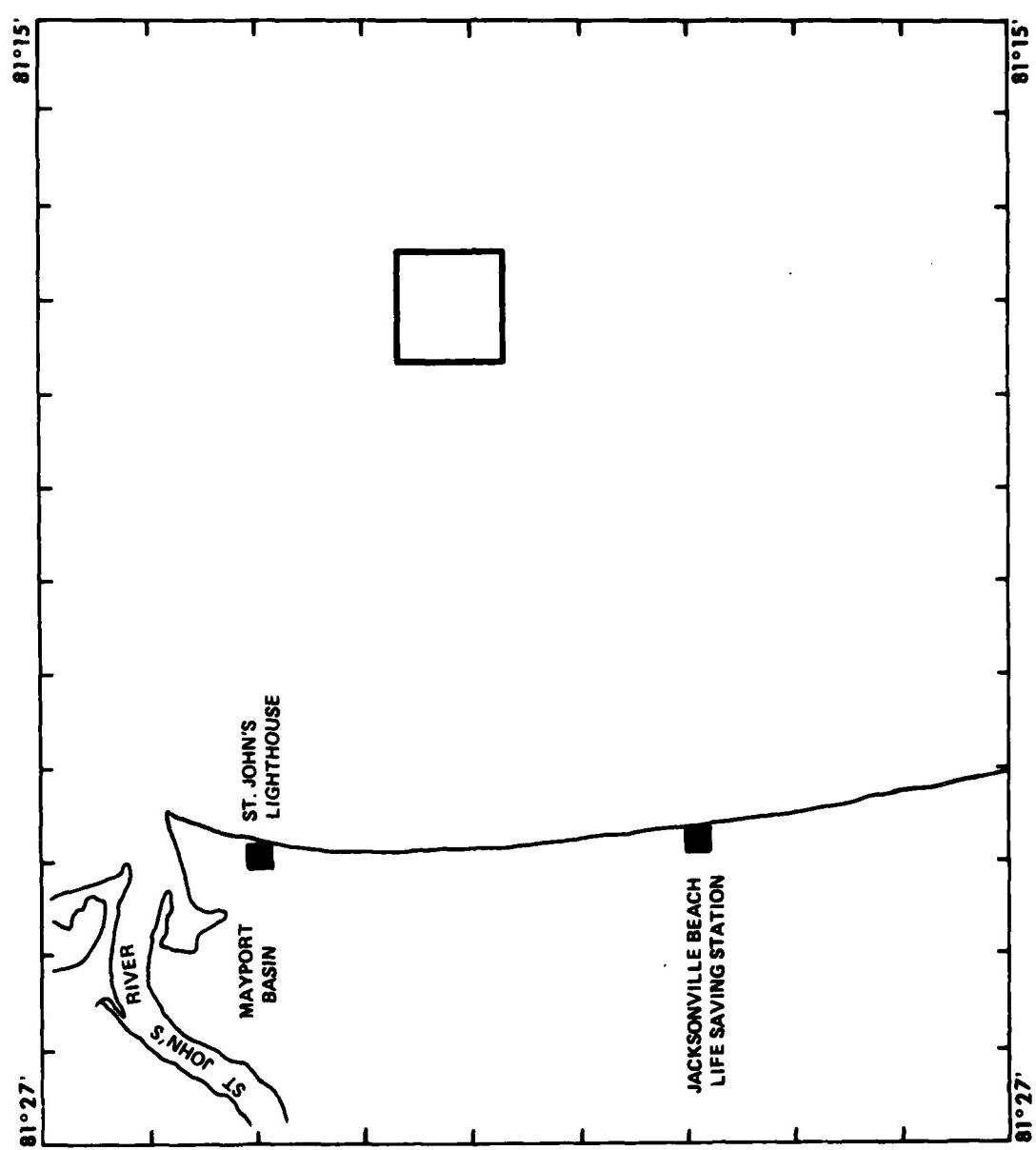


Figure 1. EPA designated disposal site

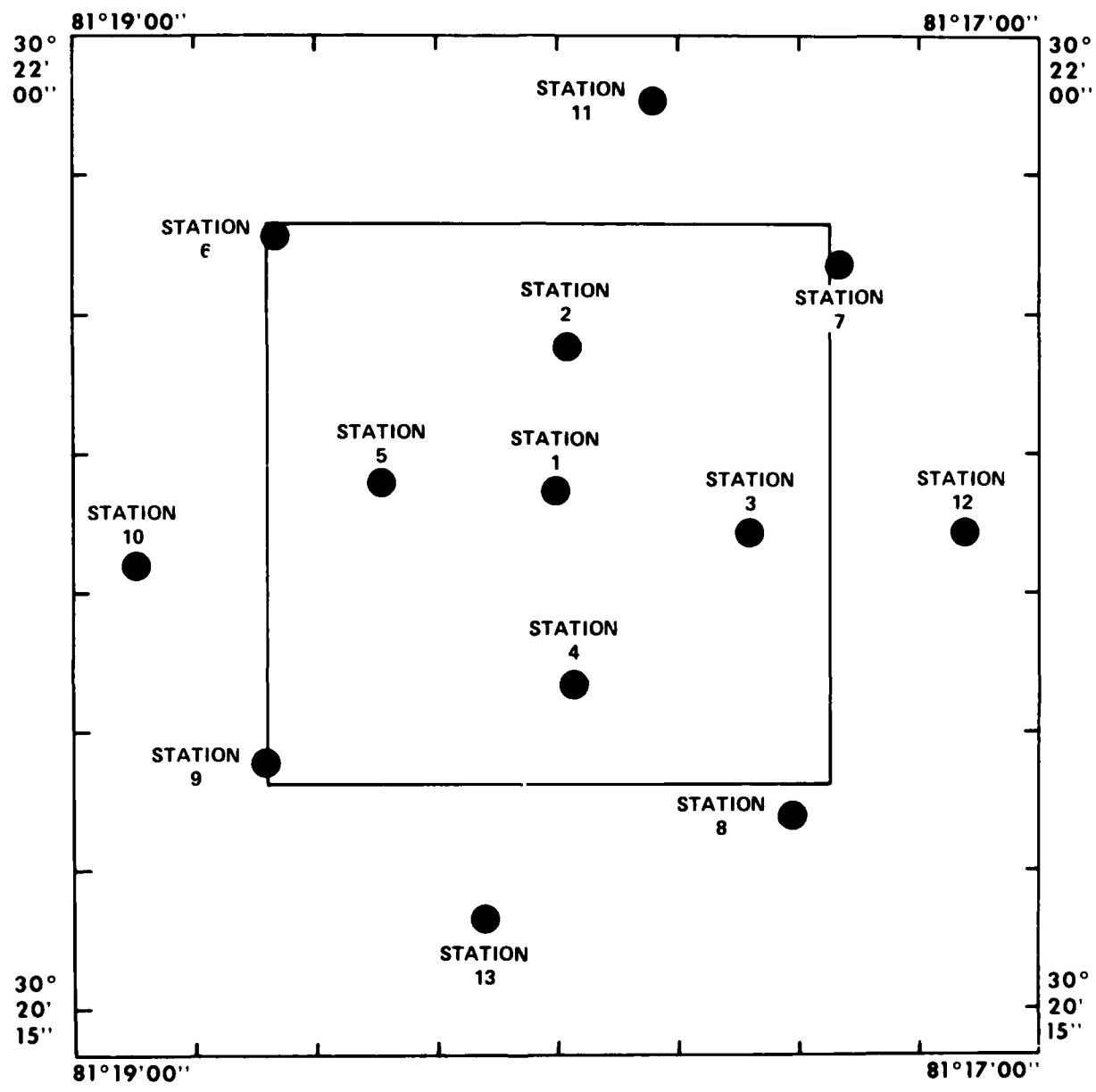


Figure 2. Sample stations and control locations for the pre-disposal survey
(February 1977)

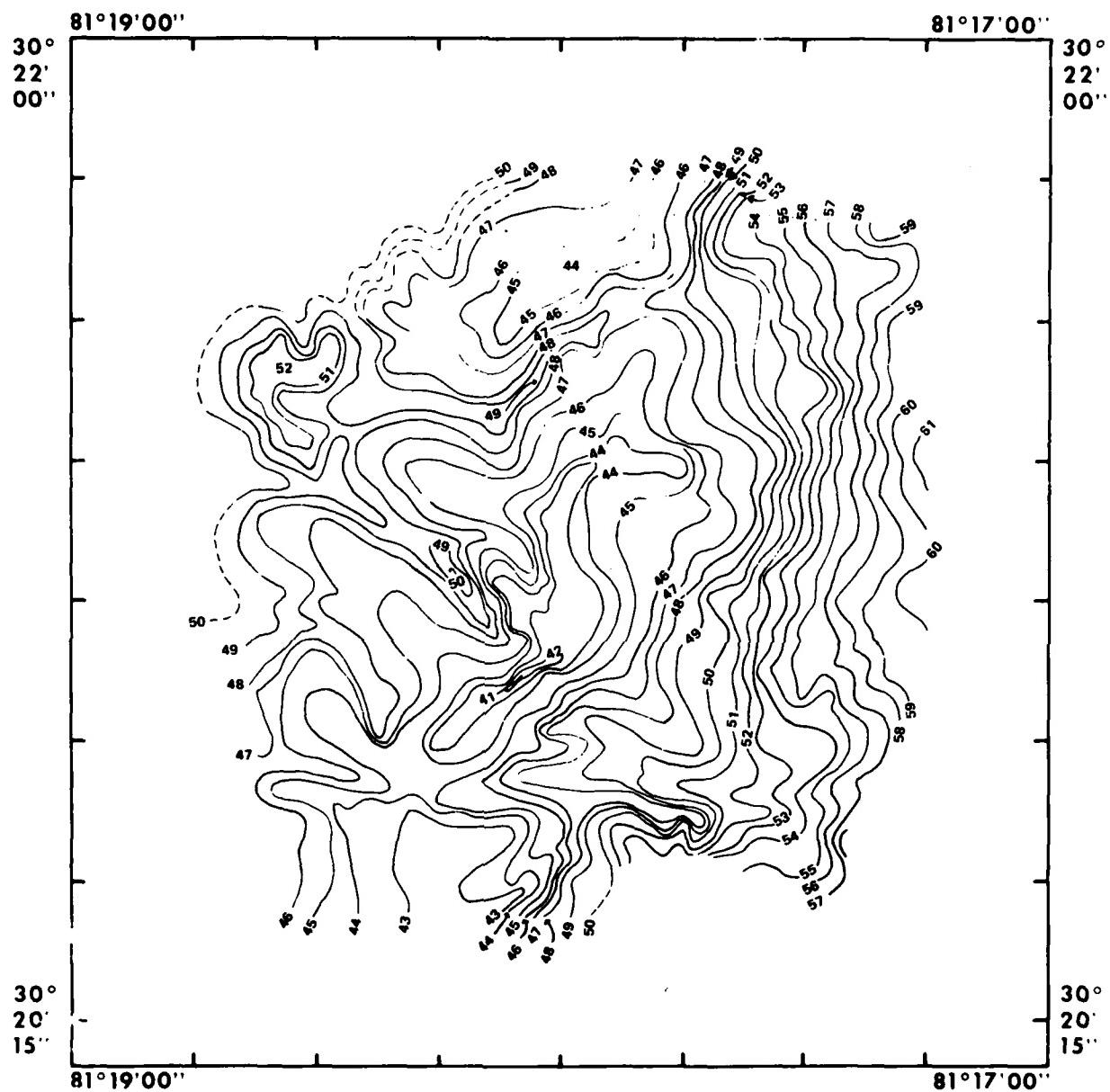


Figure 3. Bathymetric chart of operational disposal site at the time of the pre-disposal survey (February 1977)

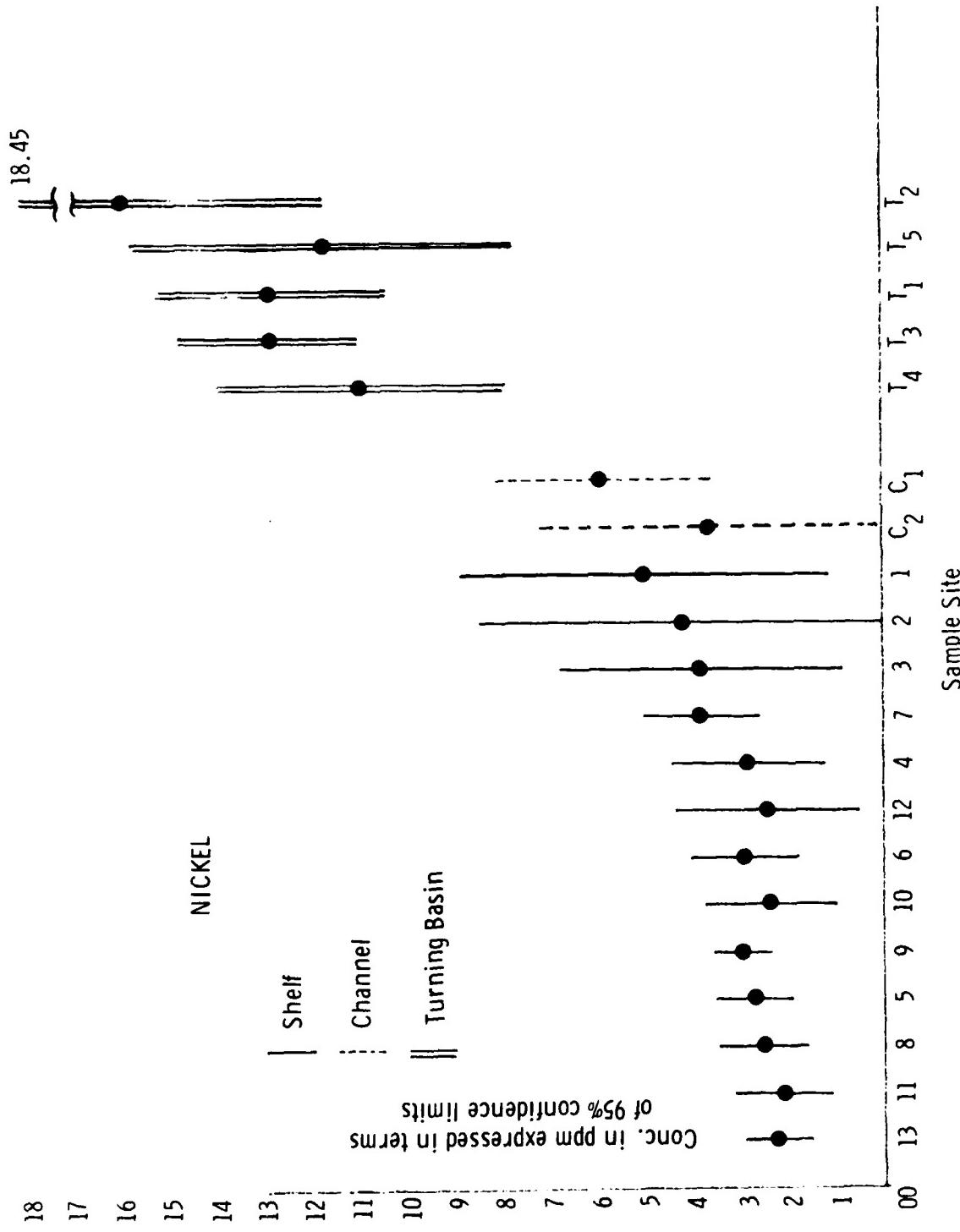


Figure 4A. Heavy metal (nickel) concentrations in ppm. Mean concentrations ± 2 standard deviations about the mean. Stations 1-13: samples from dump site; Stations C₁ and C₂: samples from channel; Stations T₁-T₅: samples from turning basin.

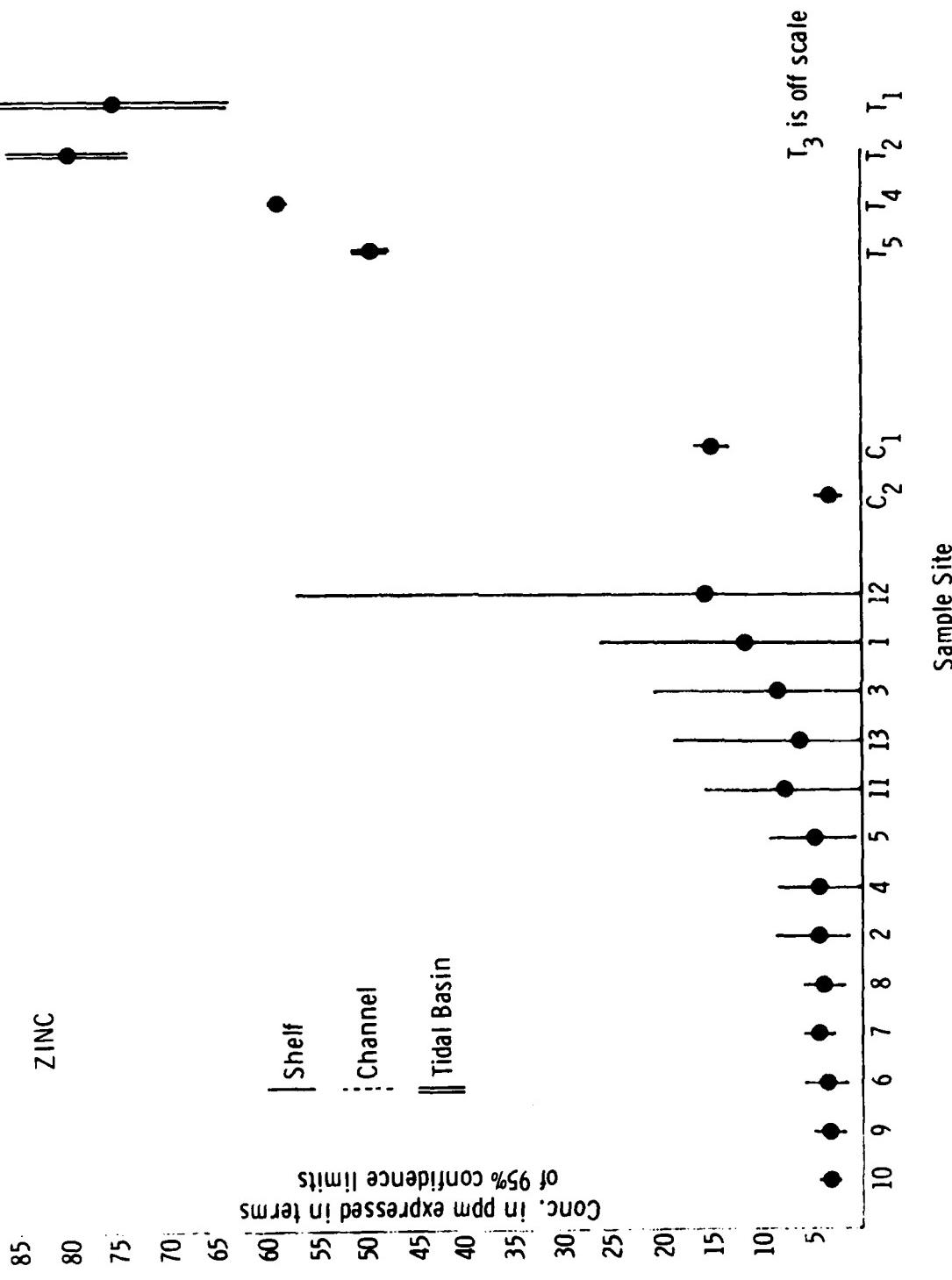


Figure 4B. Heavy metal (zinc) concentrations in ppm. Mean concentrations ± 2 standard deviations about the mean. Stations 1-13: samples from dump site; Stations C₁ and C₂: samples from channel; Stations T₁-T₅: samples from turning basin.

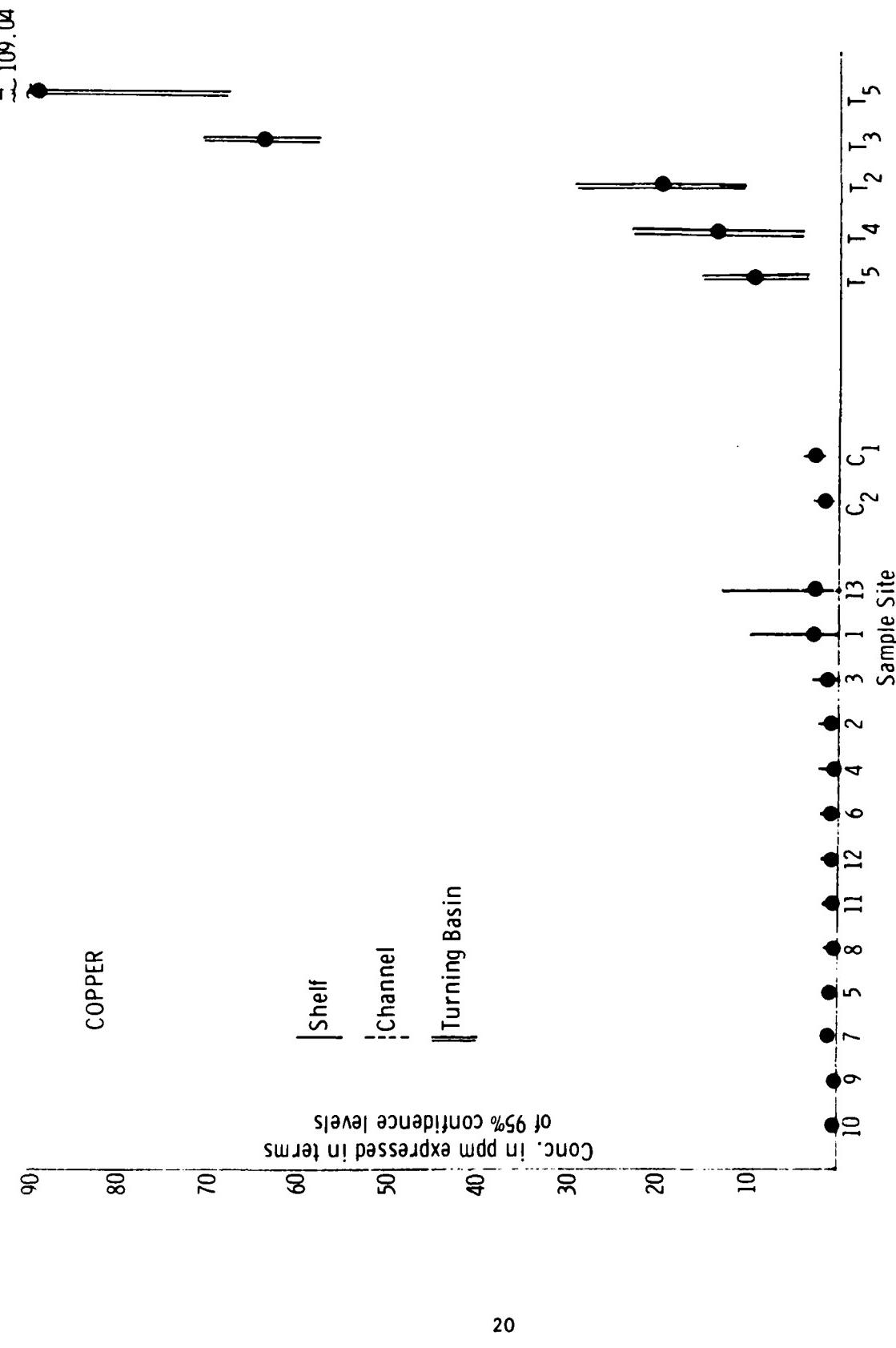


Figure 4C. Heavy metal (copper) concentrations in ppm. Mean concentrations ± 2 standard deviations about the mean. Stations 1-13: samples from dump site; Stations C₁ and C₂: samples from channel; Stations T₁-T₅: samples from turning basin.

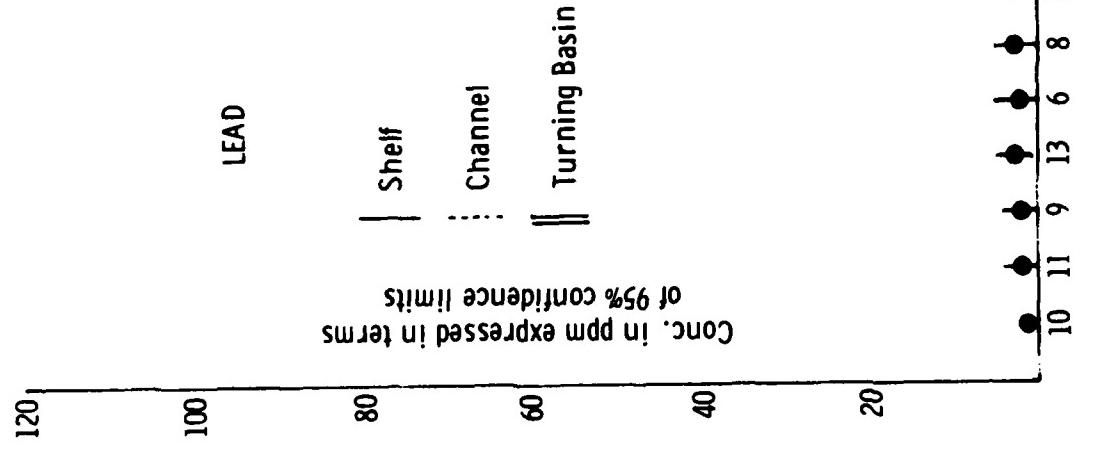


Figure 4D. Heavy metal (lead) concentrations in ppm. Mean concentrations ± 2 standard deviations about the mean. Stations 1-13: samples from dump site; Stations C₁ and C₂: samples from channel; Stations T₁-T₅: samples from turning basin.

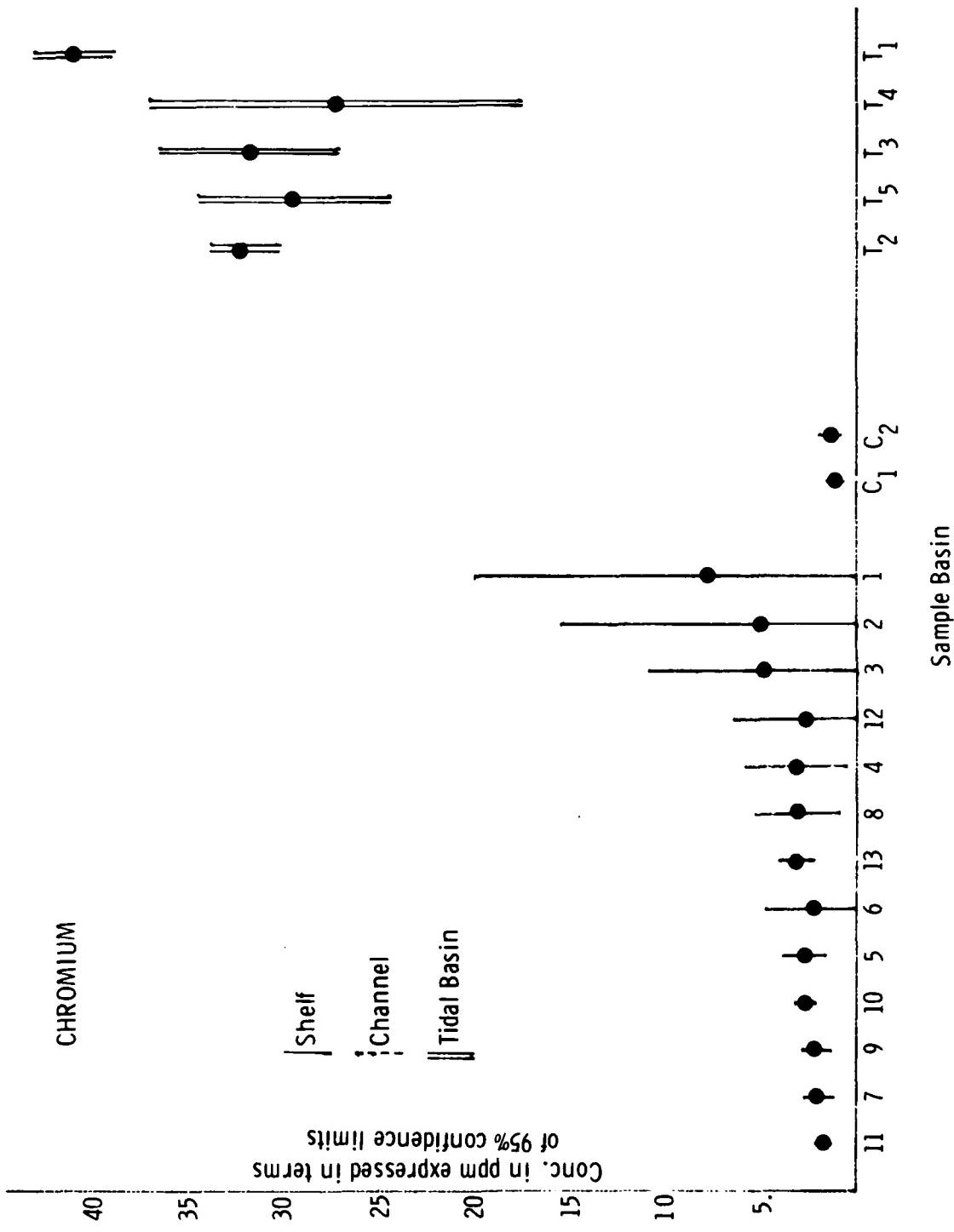


Figure 4E. Heavy metal (chromium) concentrations in ppm. Mean concentrations ± 2 standard deviations about the mean. Stations 1-13: samples from dump site; Stations C₁ and C₂: samples from channel; Stations T₁-T₅: samples from turning basin.

CADMUM

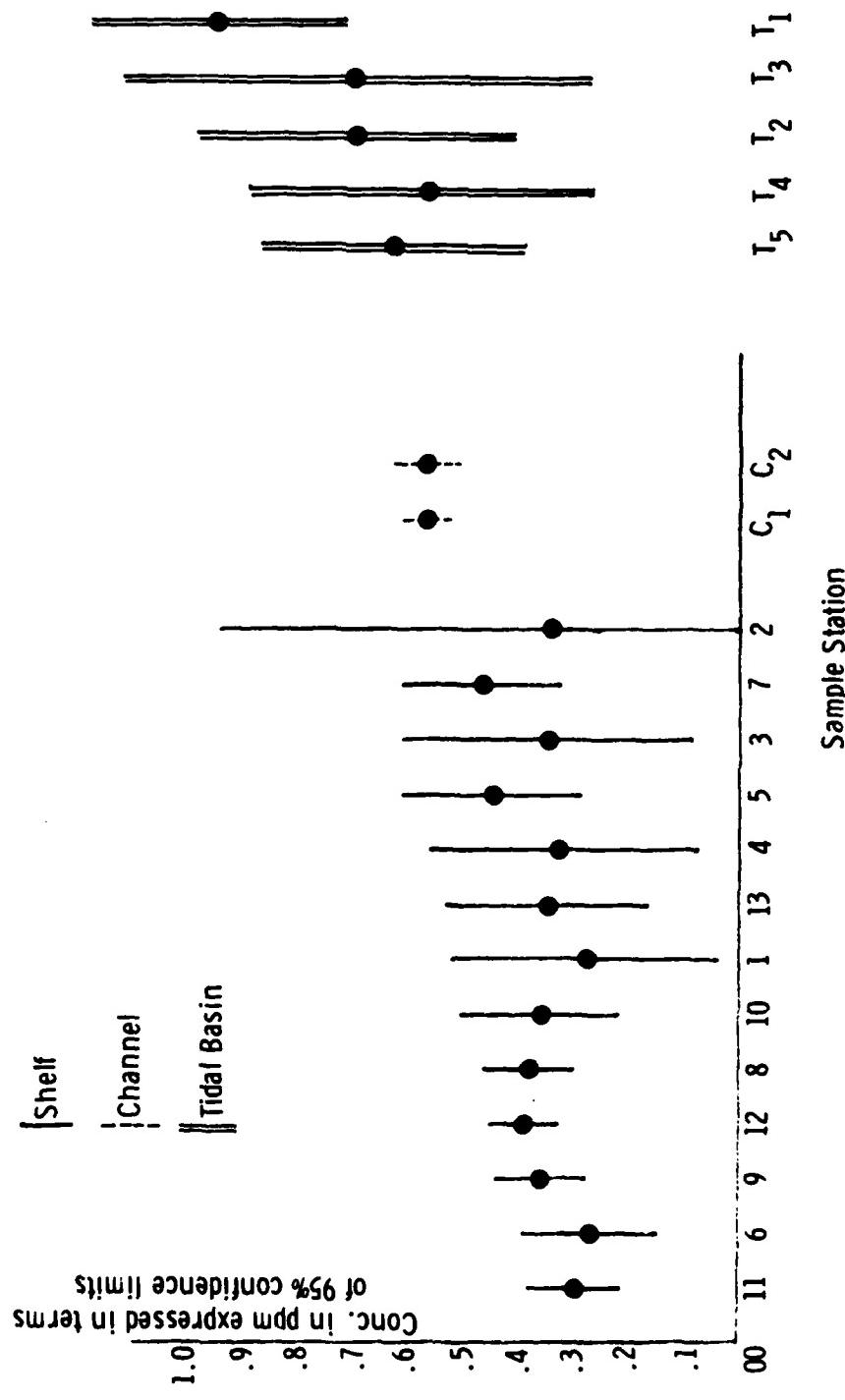


Figure 4F. Heavy metal (cadmium) concentrations in ppm. Mean concentrations ± 2 standard deviations about the mean. Stations 1-13: samples from dump site; Stations C₁ and C₂: samples from the channel; Stations T₁-T₅: samples from turning basin.

NICKEL

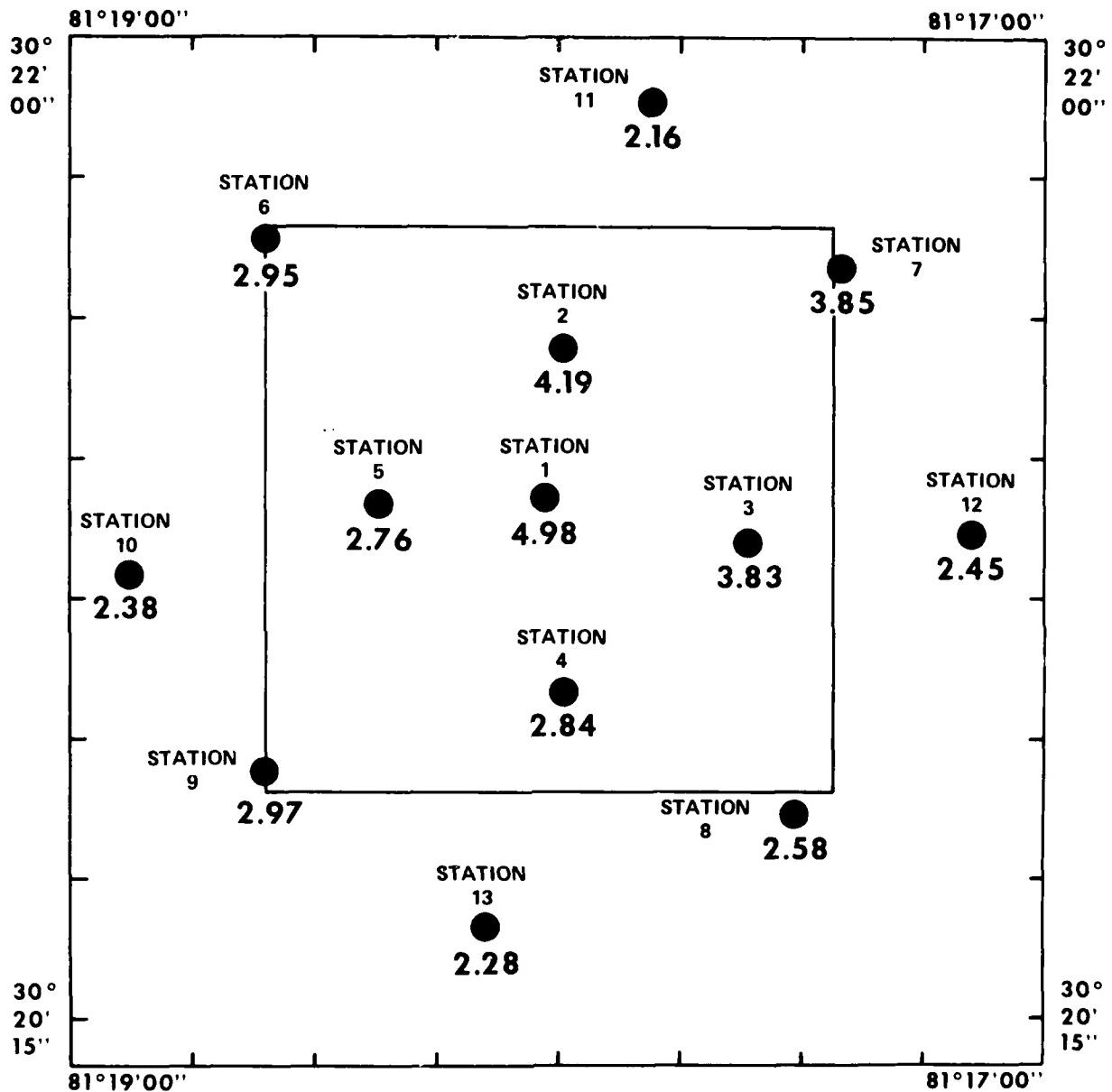


Figure 5. Nickel (Ni) concentrations (ppm) in sediments from stations within the disposal site and from control stations

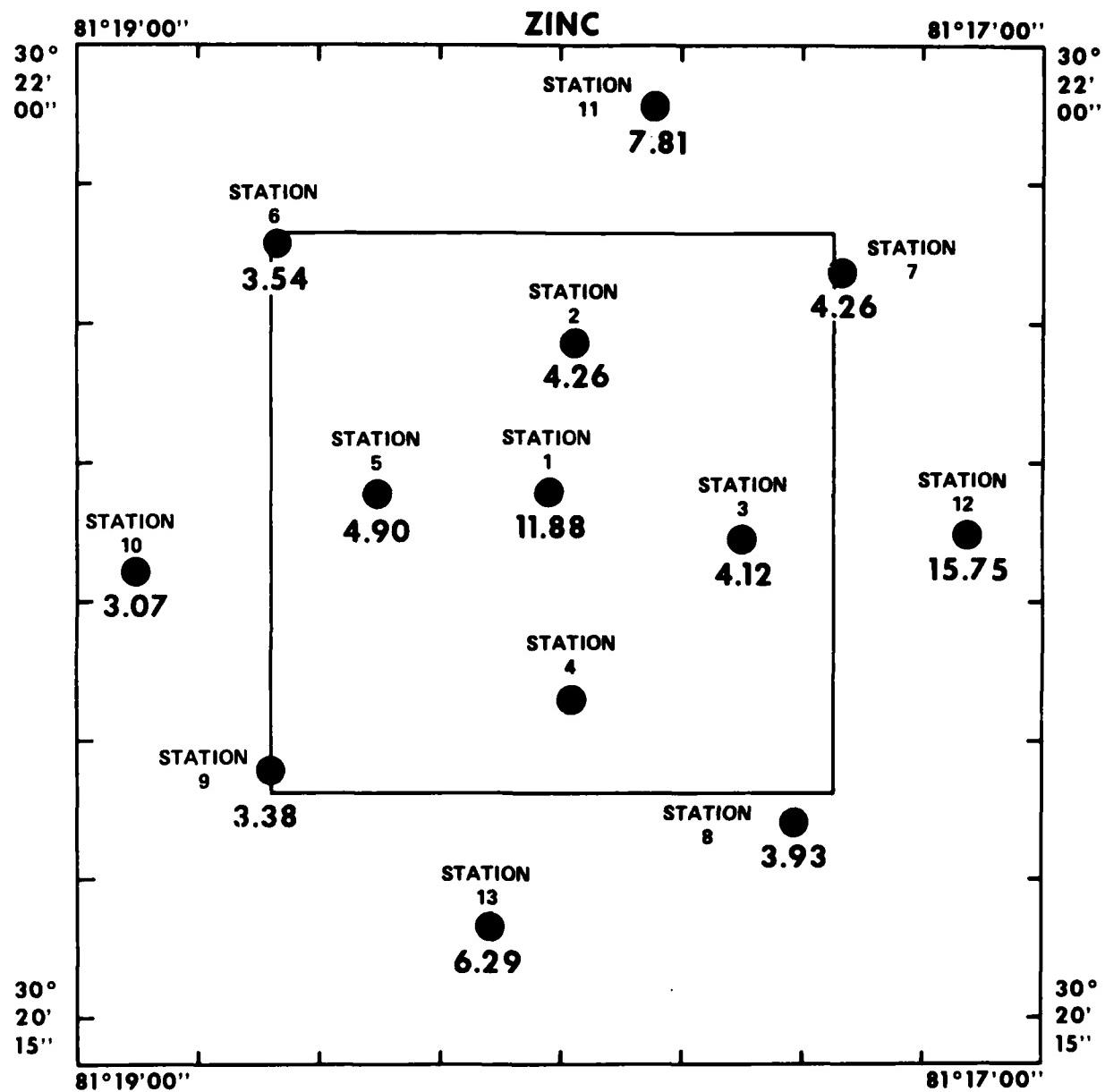


Figure 6. Zinc (Zn) concentrations (ppm) in sediments from stations within the disposal site and from control stations

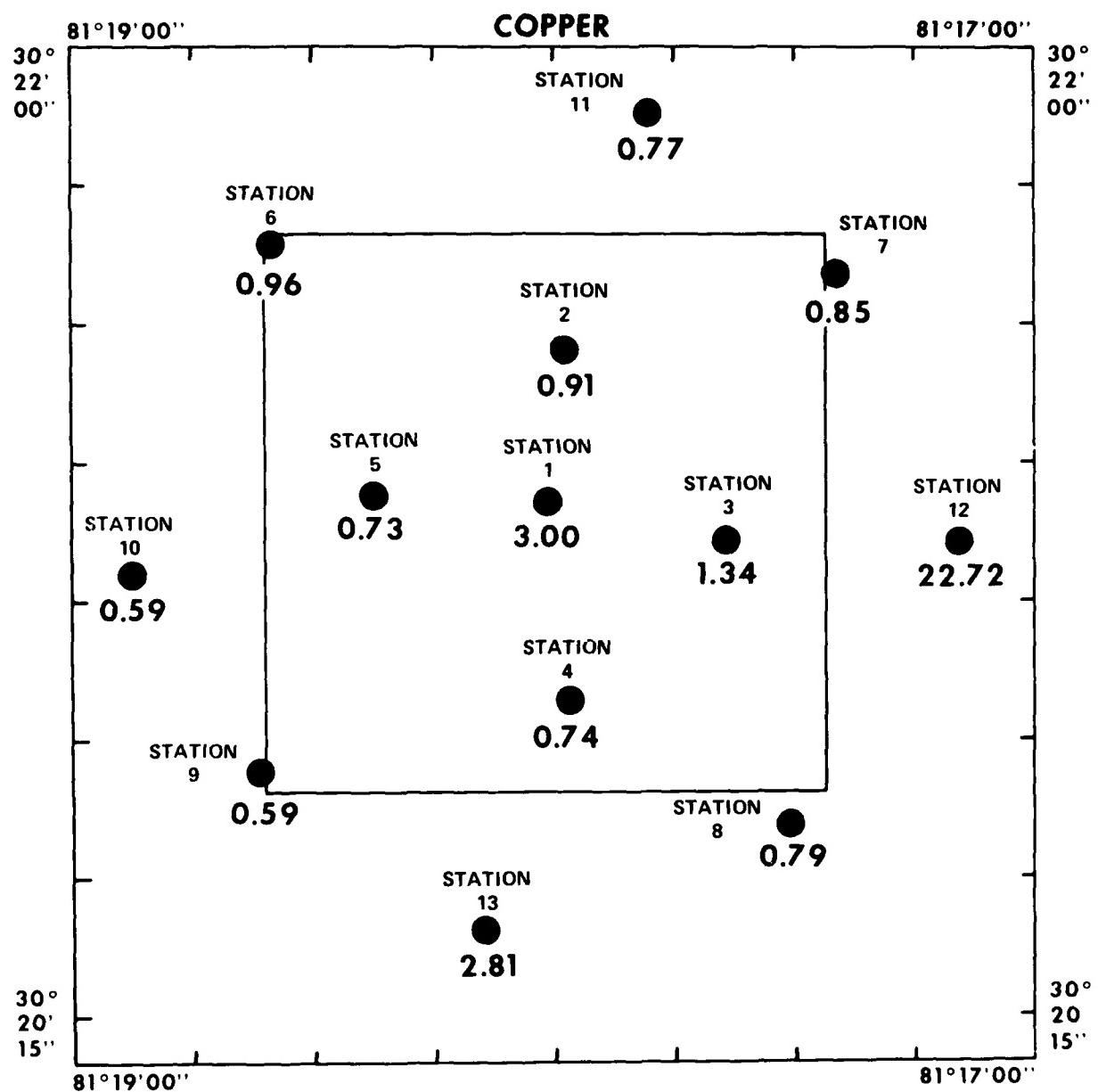


Figure 7. Copper (Cu) concentrations (ppm) in sediments from stations within the disposal site and from control stations

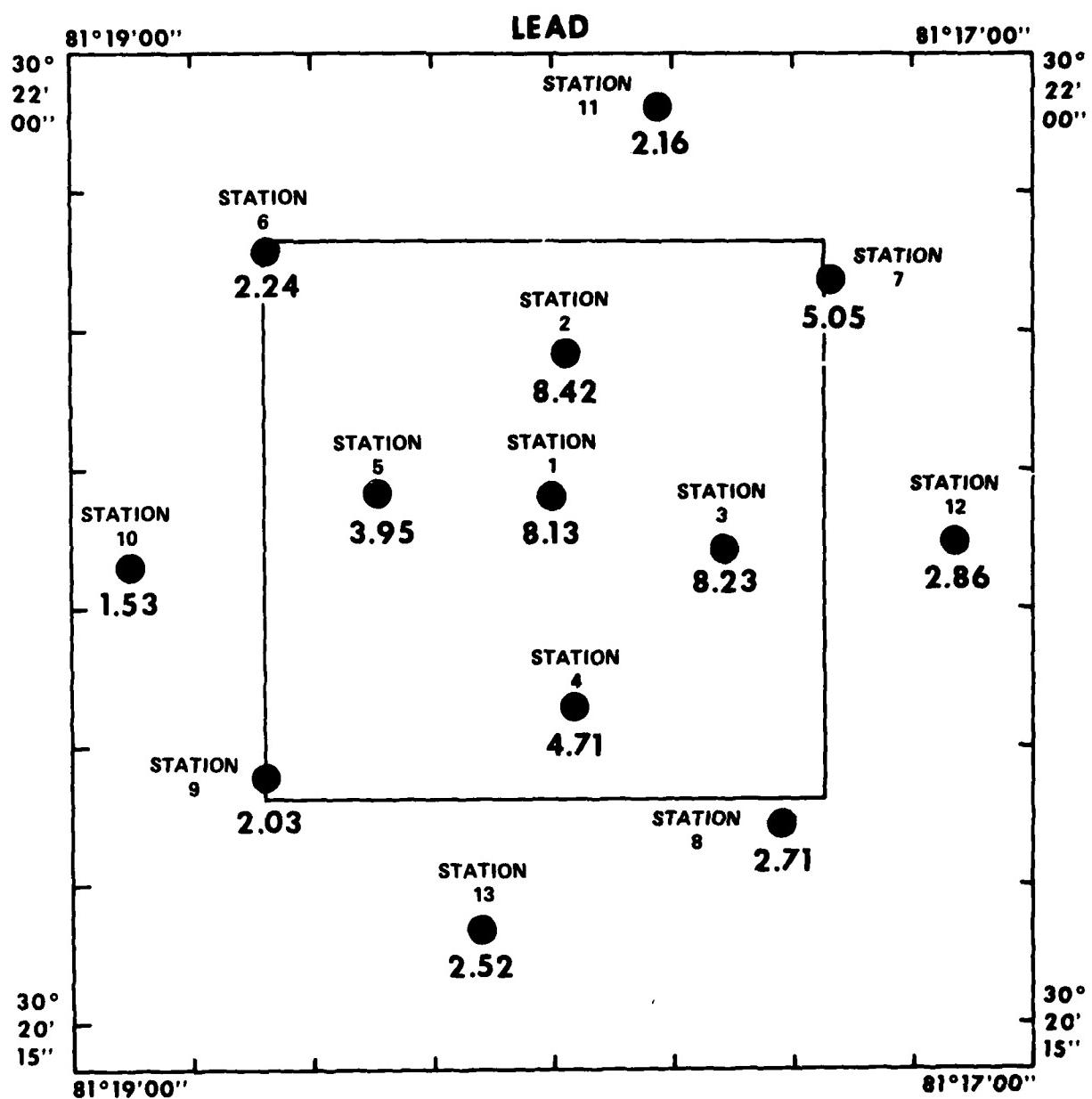


Figure 8. Lead (Pb) concentrations (ppm) in sediments from stations within the disposal site and from control stations

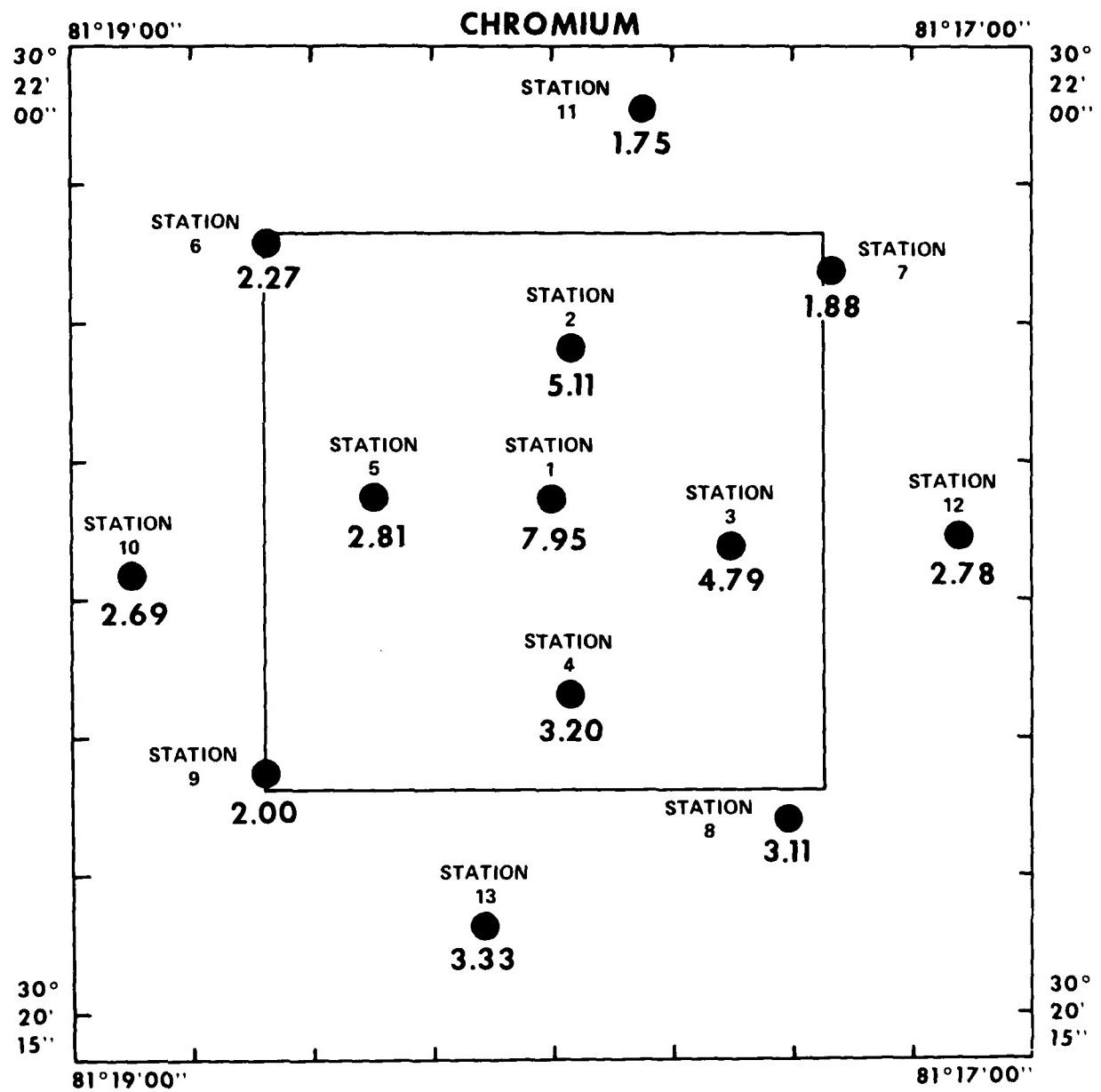


Figure 9. Chromium (Cr) concentrations (ppm) in sediments from stations within the disposal site and from control stations

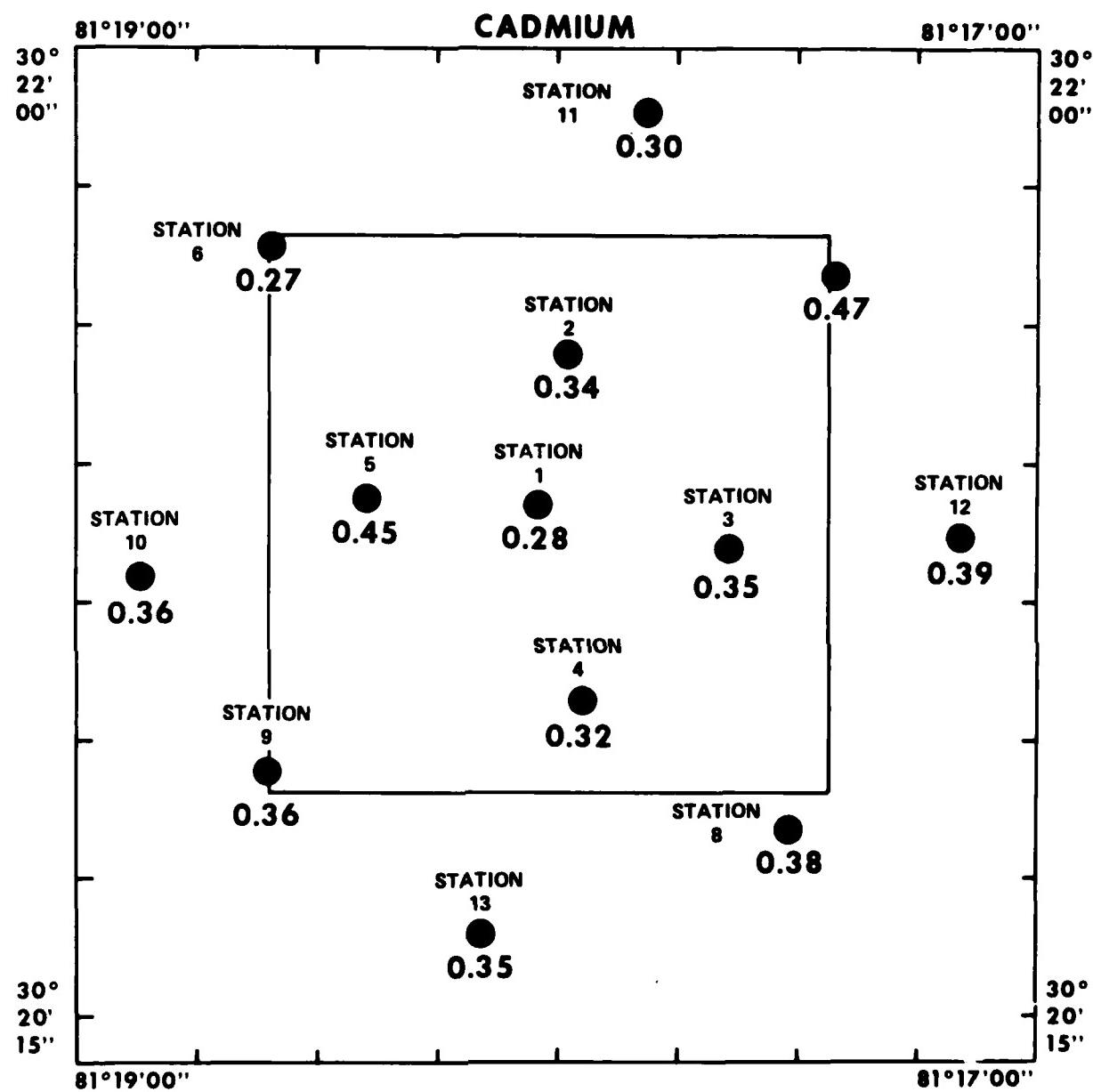


Figure 10. Cadmium (Ca) concentrations (ppm) in sediments from stations within the disposal site and from control stations

PERCENT CLAY AND SILT

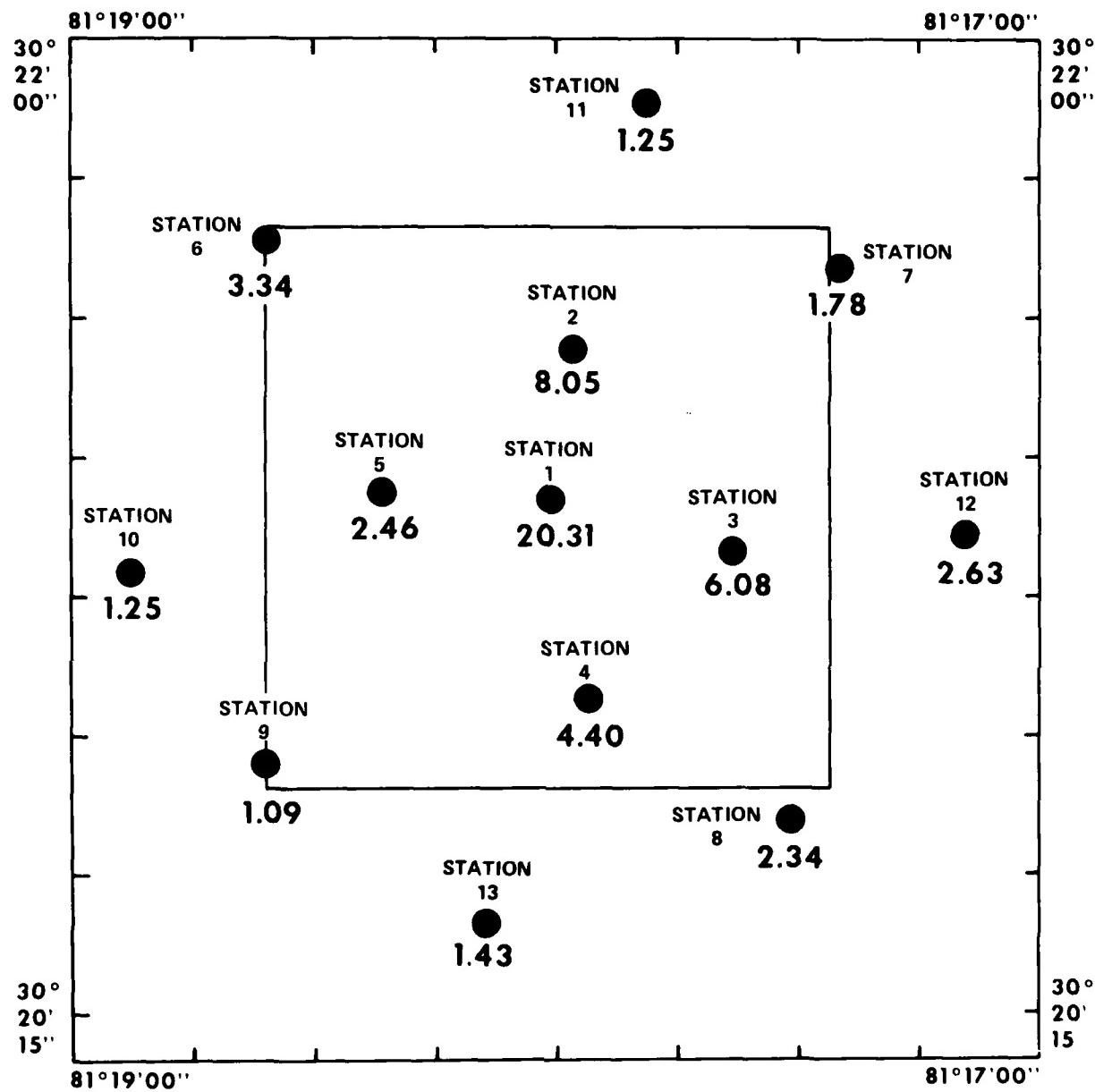


Figure 11. Sediment composition data (percent of silt and clay)

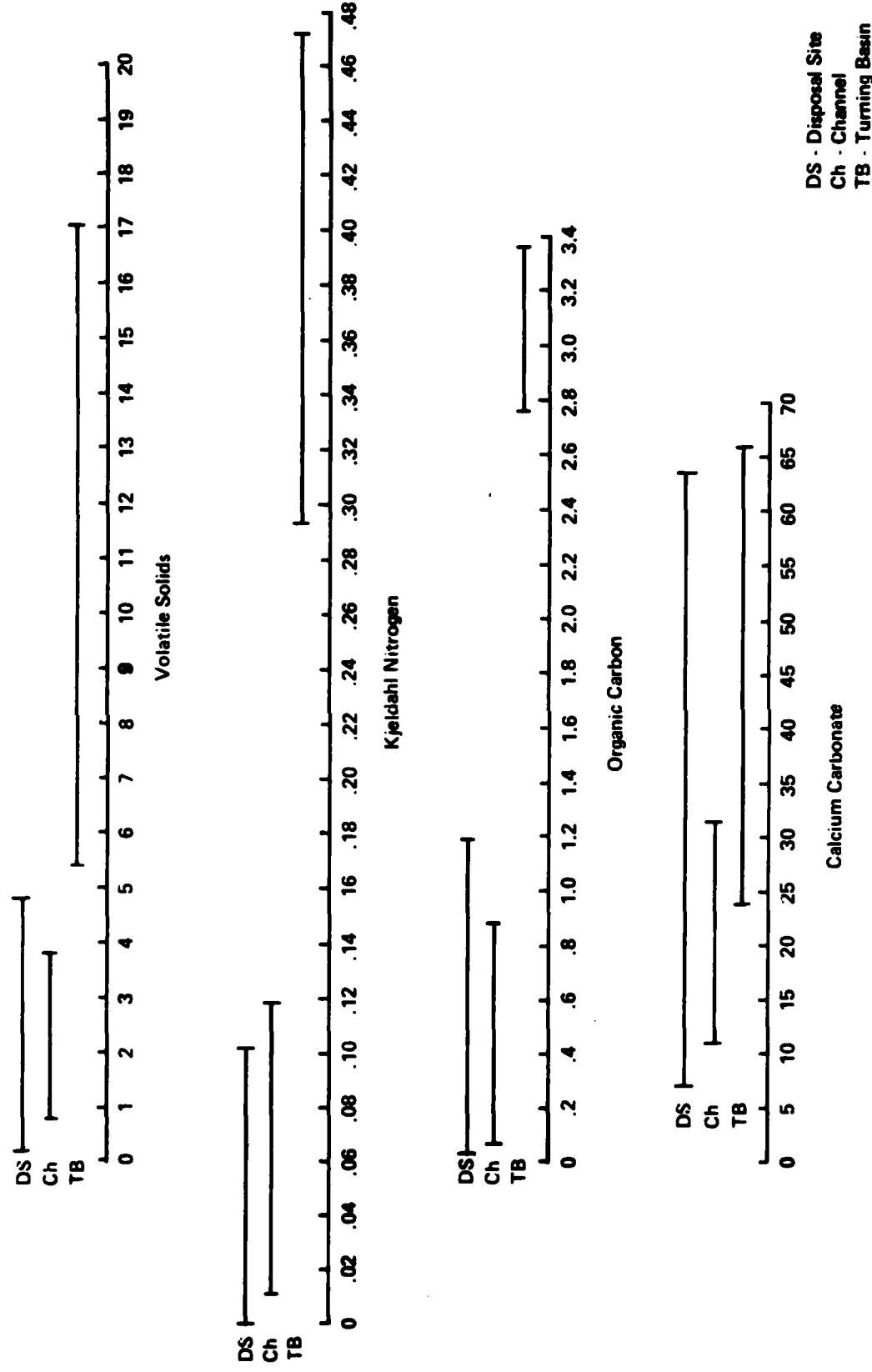


Figure 12. Ranges of percent volatile solids, percent Kjeldahl nitrogen, percent organic carbon, and percent calcium carbonate (percent total of dry weight of sample) for individual samples from the disposal site, channel and turning basin.

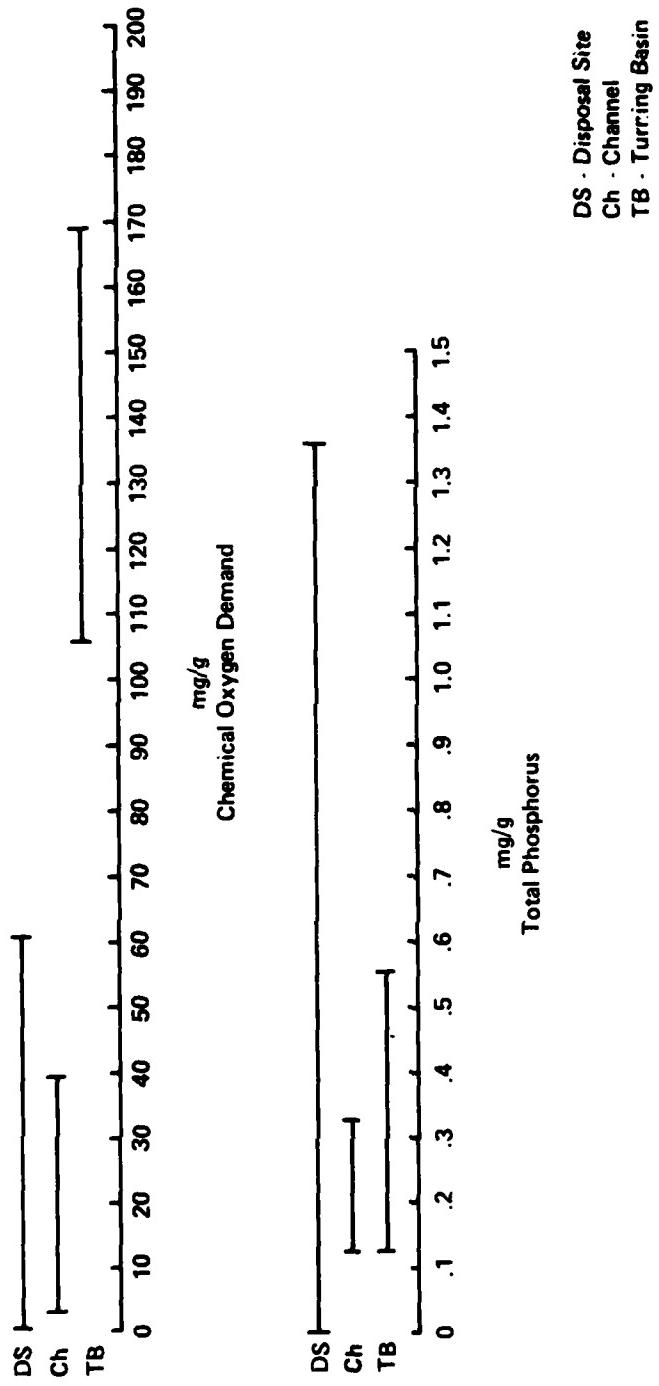


Figure 13. Range of values for COD and total phosphorus (mg per g of sample) for individual samples from the disposal site, channel and turning basin.

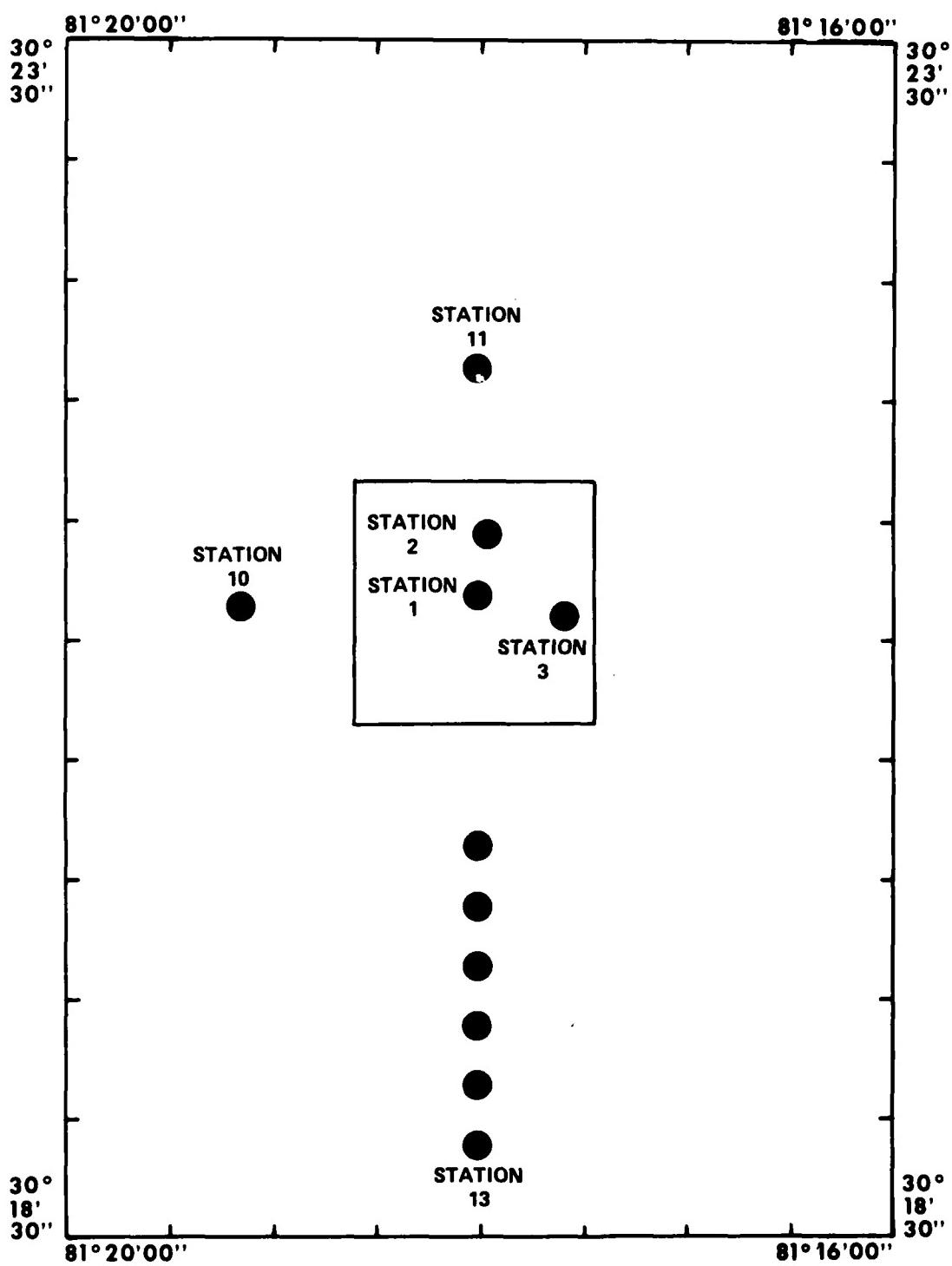


Figure 14. Locations of w/in disposal site stations 1, 2, and 3 in relation to areal control stations 10, 11, and 13 taken in September 1977

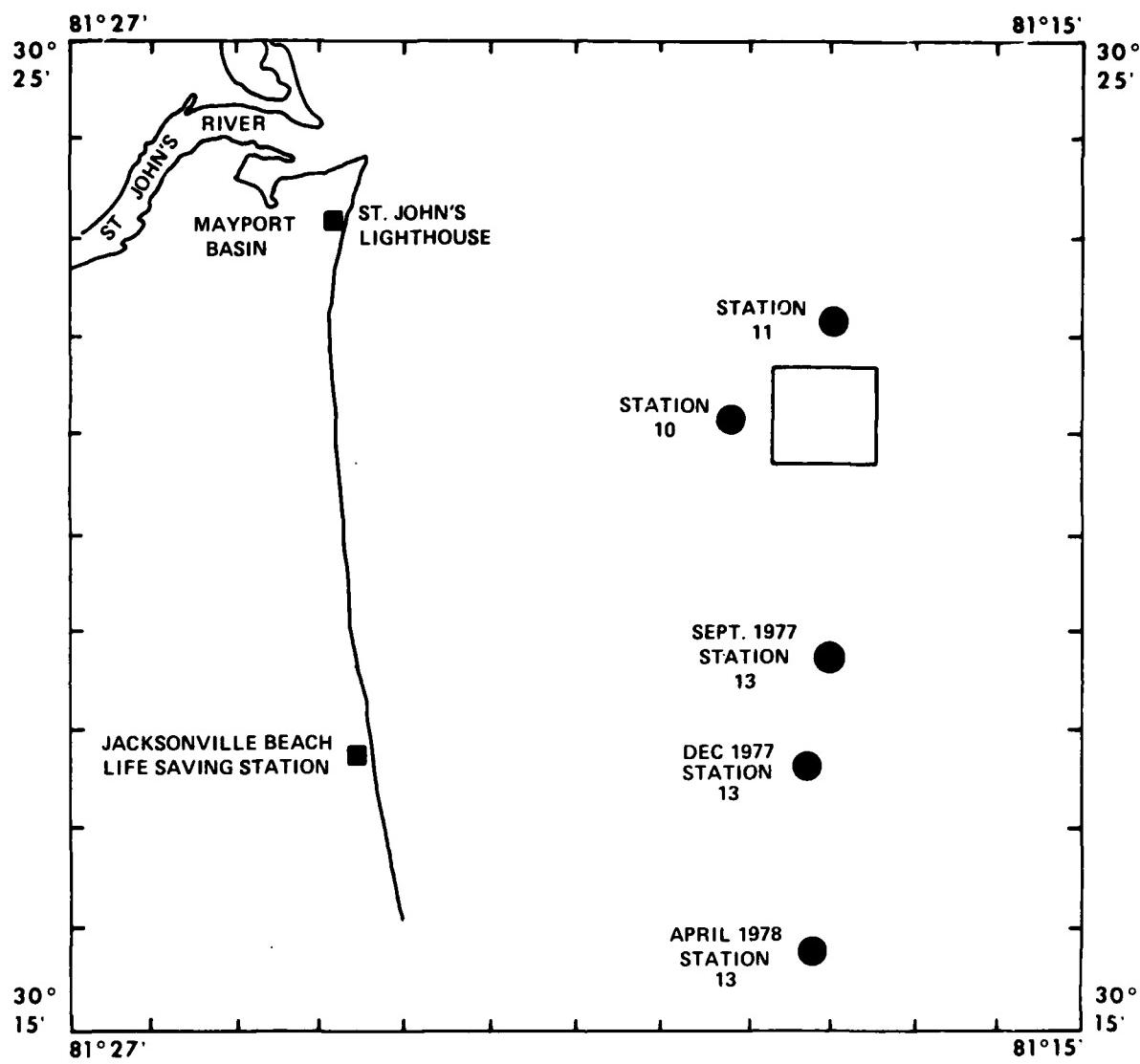


Figure 15. Relationship of areal control stations 10, 11, and 13 to the disposal site in December 1977 and April 1978

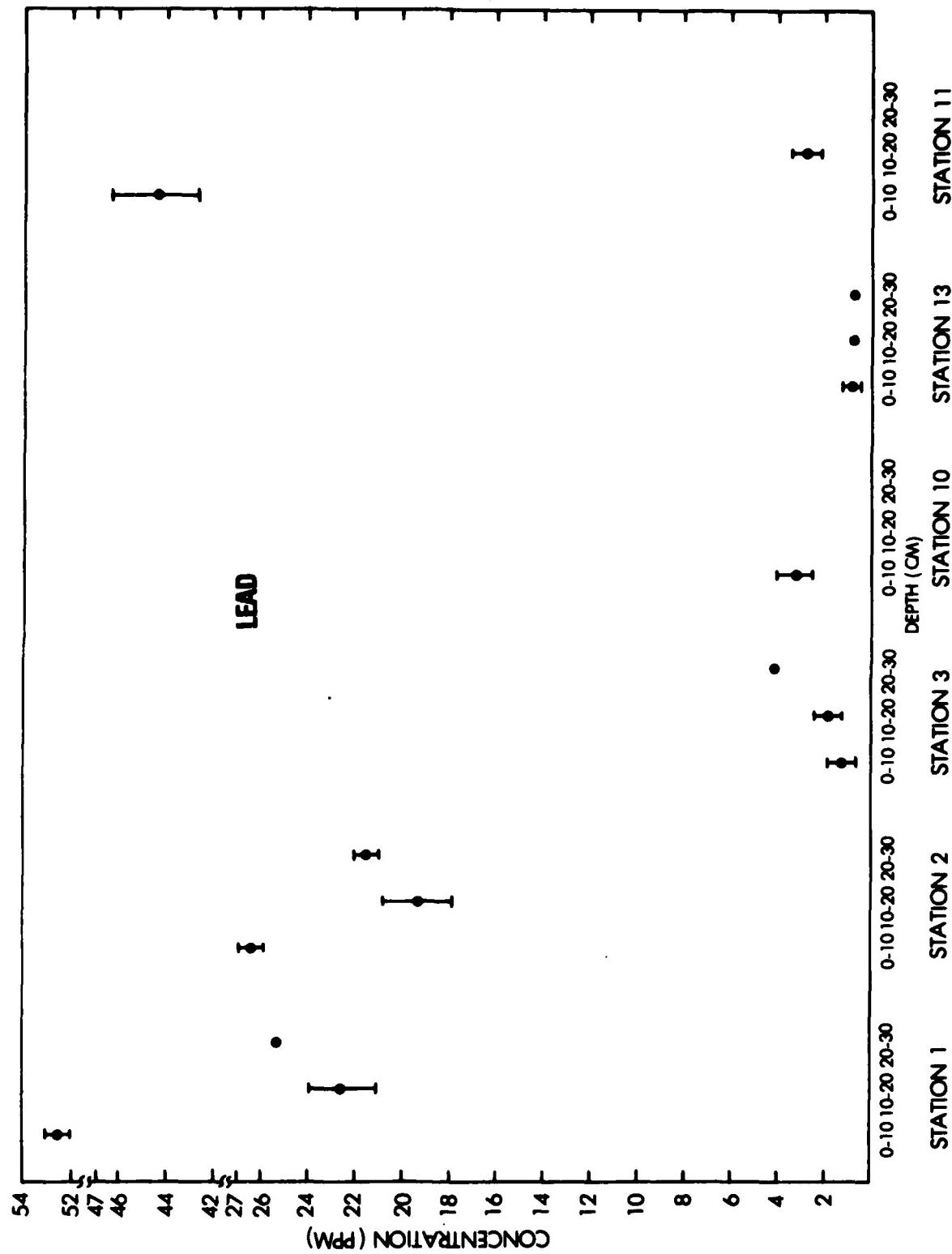


Figure 16A. Concentration of lead in ppm displayed as the mean of three replicate samples for each 10 cm depth \pm standard error

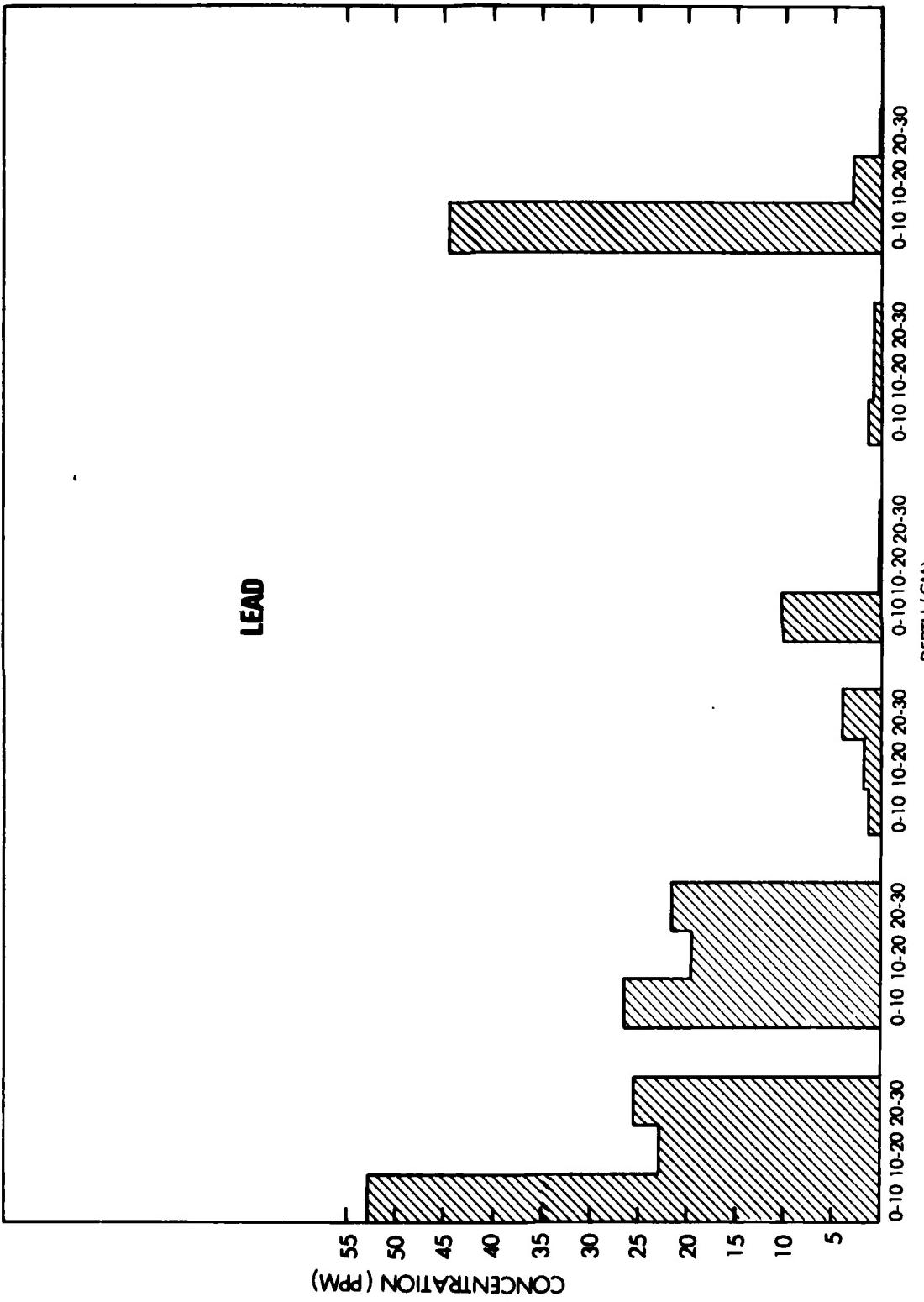
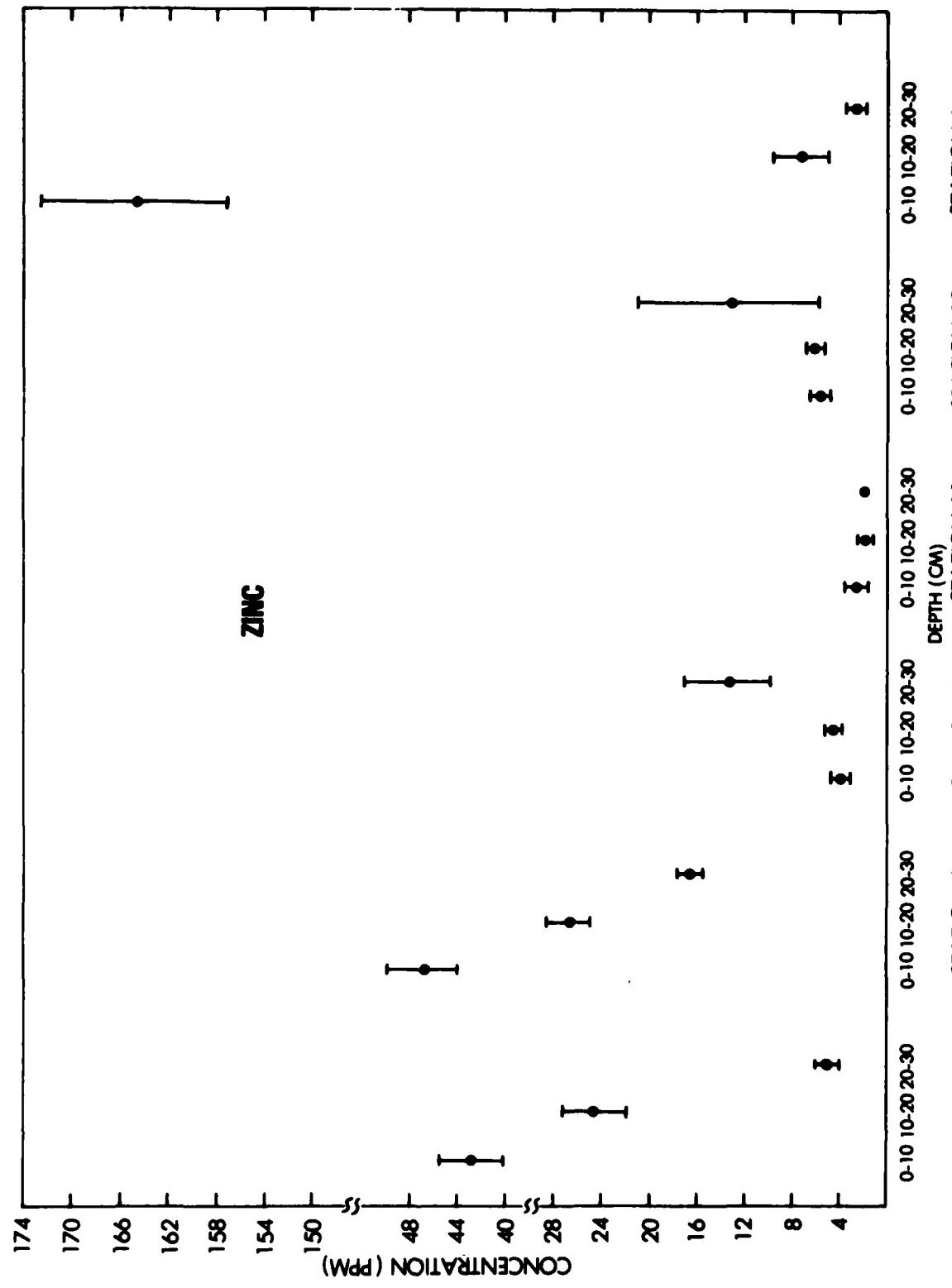


Figure 16B. Concentration of lead in ppm displayed as the mean of three replicate samples for each 10 cm depth



STATION 11

STATION 13

STATION 10

STATION 3

STATION 2

STATION 1

DEPTH (CM)

ZINC

Figure 17A. Concentration of zinc in ppm displayed as the mean of three replicate samples for each 10 cm depth \pm standard error

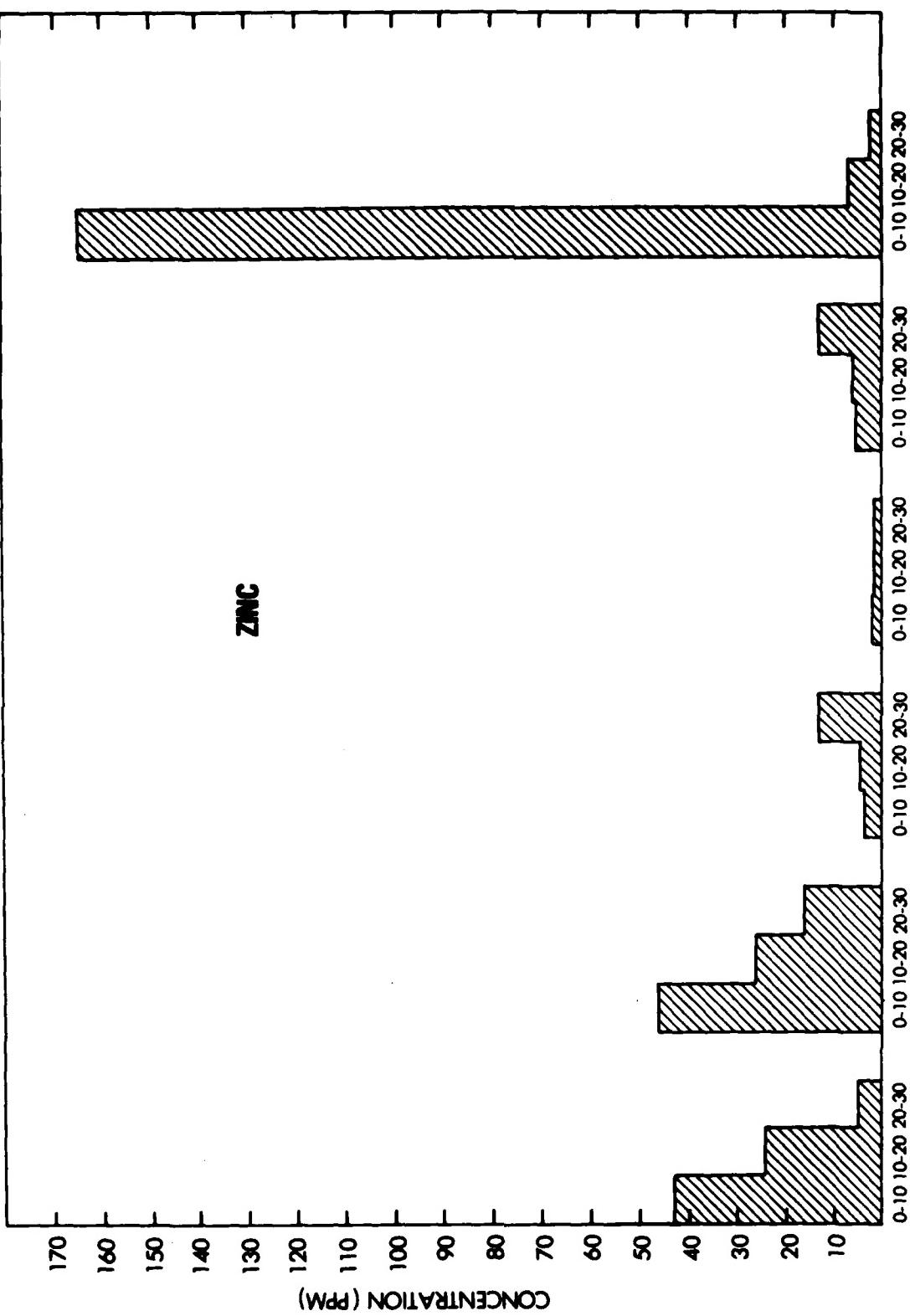


Figure 17B. Concentration of zinc in ppm displayed as the mean of three replicate samples for each 10 cm depth

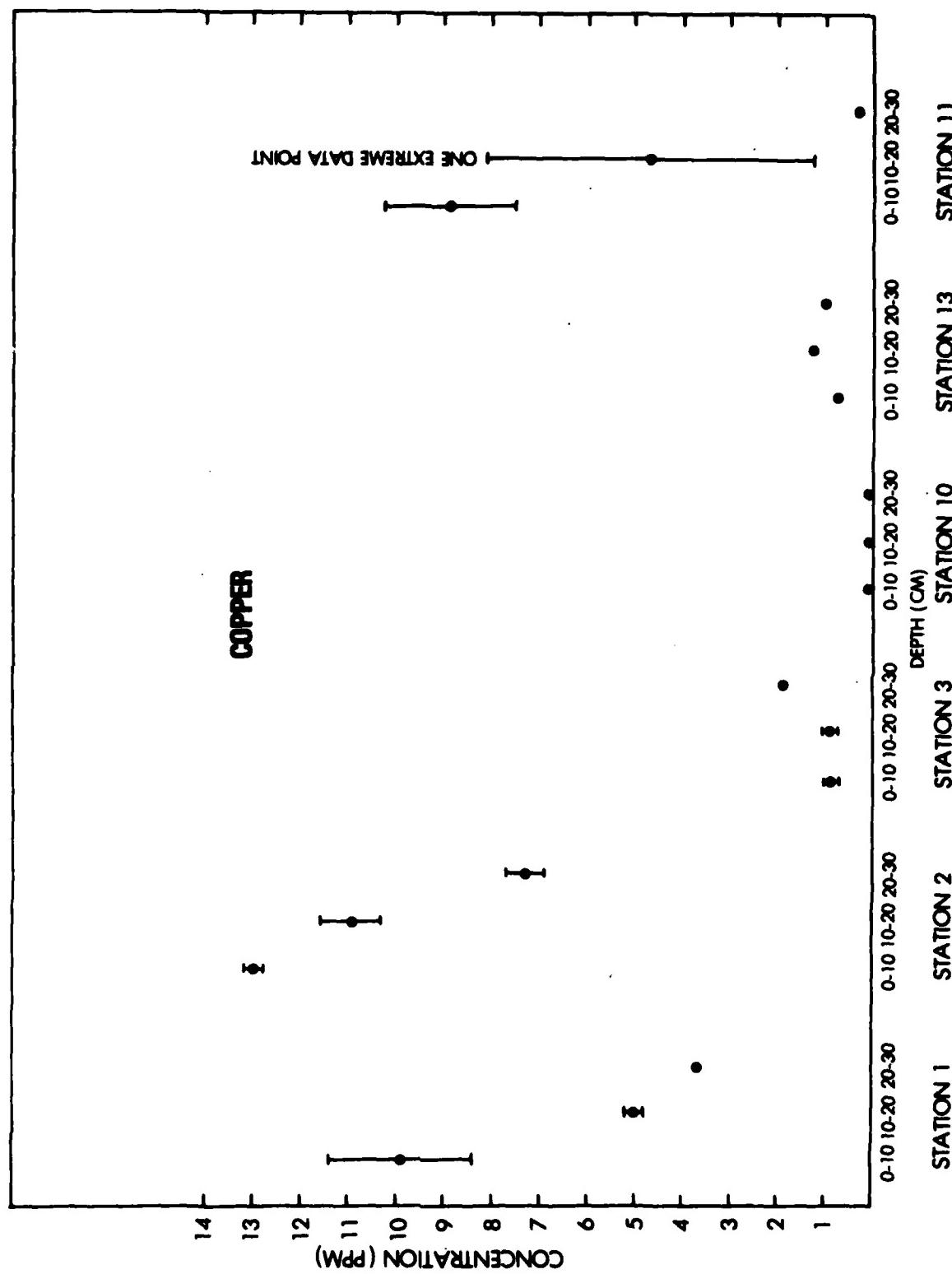


Figure 18A. Concentration of copper in ppm displayed as the mean of three replicate samples for each 10 cm depth \pm standard error

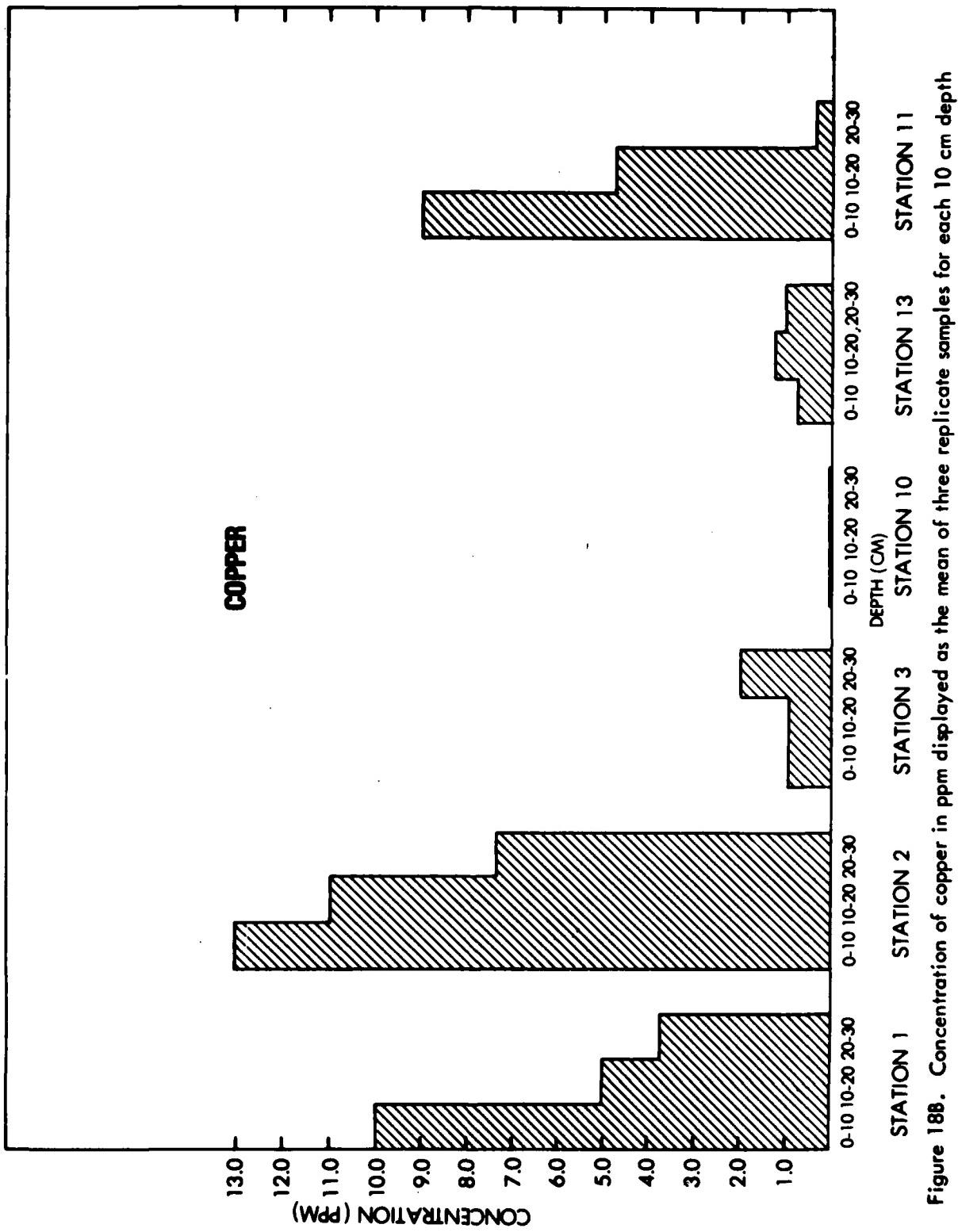


Figure 18B. Concentration of copper in ppm displayed as the mean of three replicate samples for each 10 cm depth

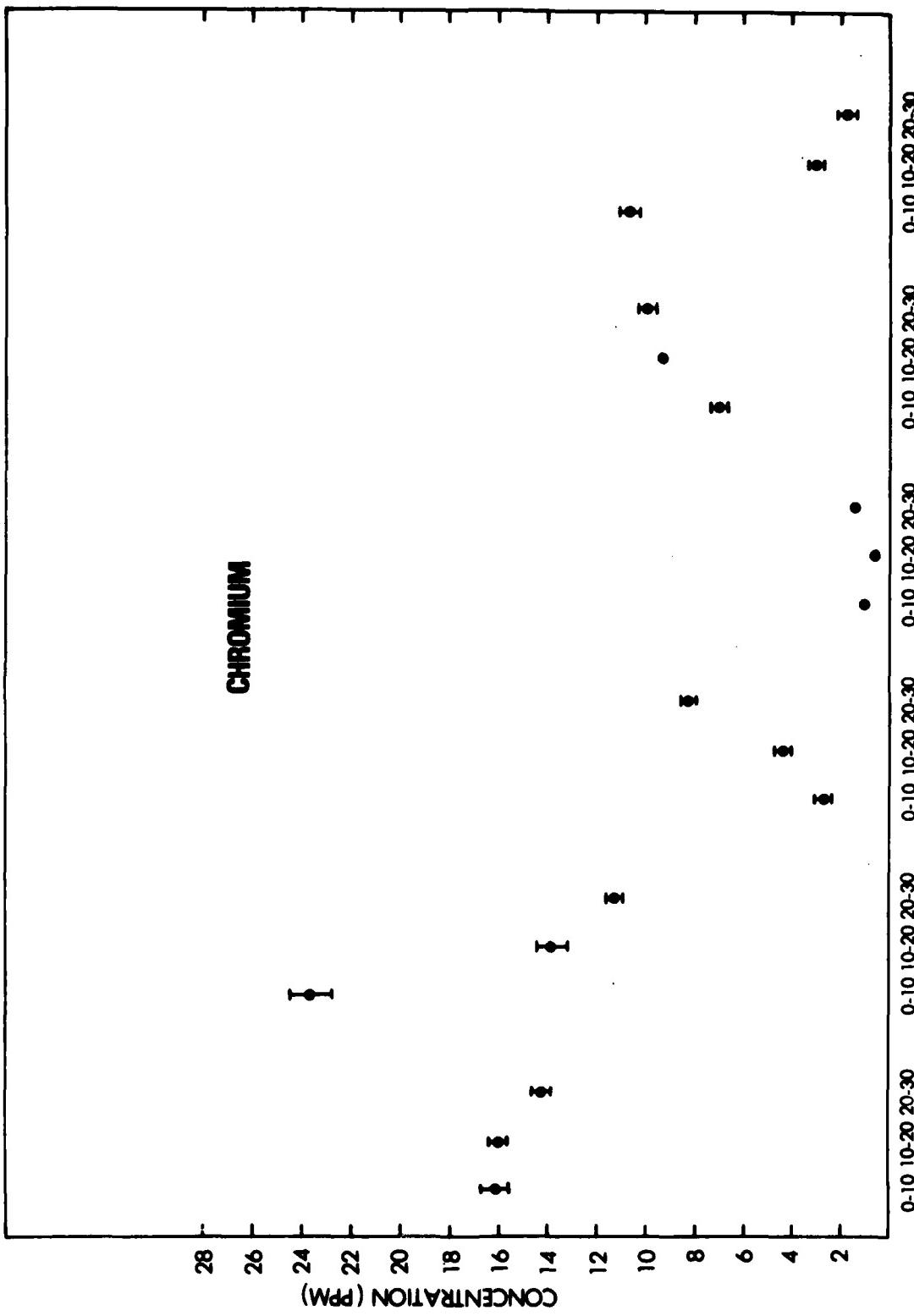


Figure 19A. Concentration of chromium in ppm displayed as the mean of three replicate samples for each 10 cm depth \pm standard error

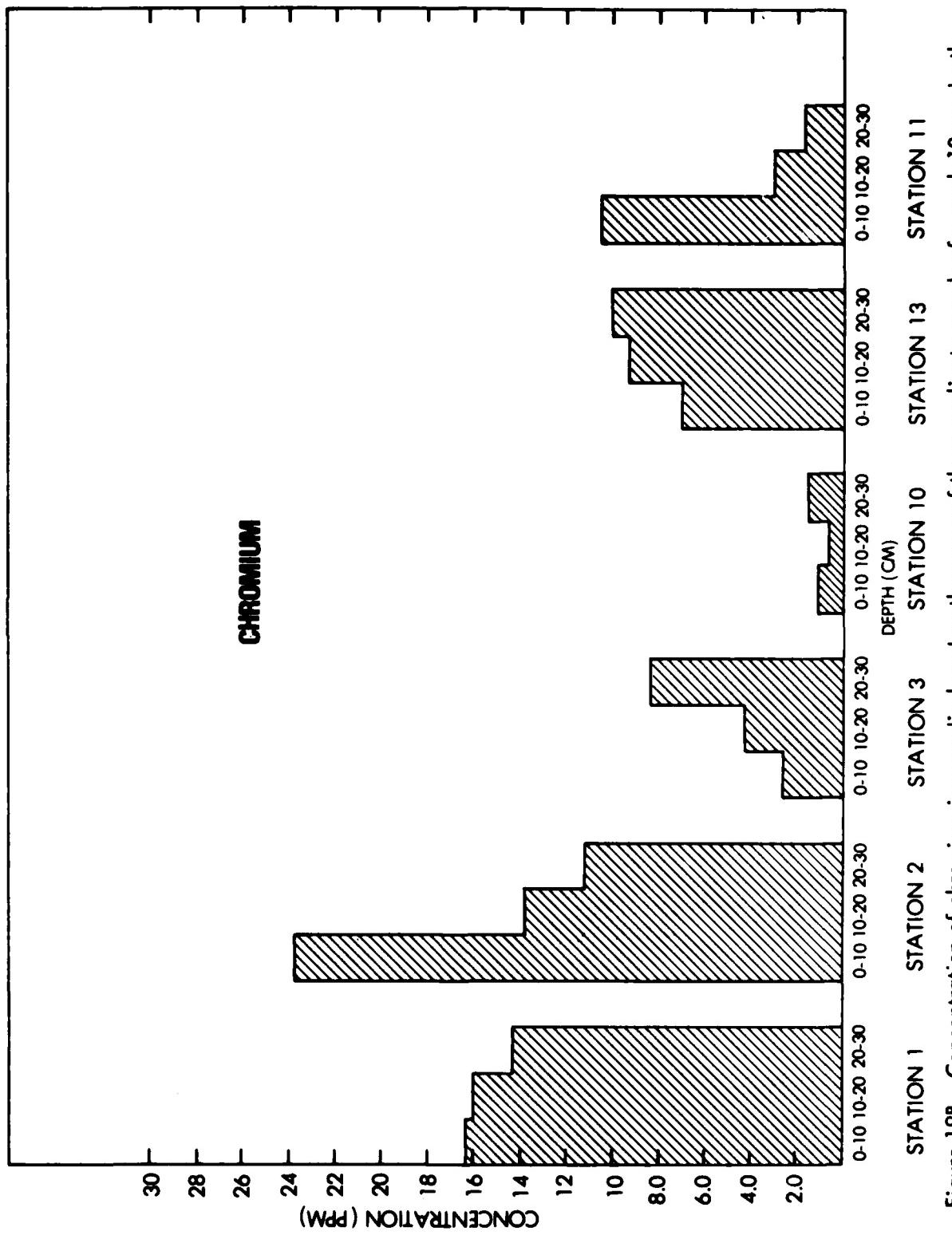


Figure 19B. Concentration of chromium in ppm displayed as the mean of three replicate samples for each 10 cm depth

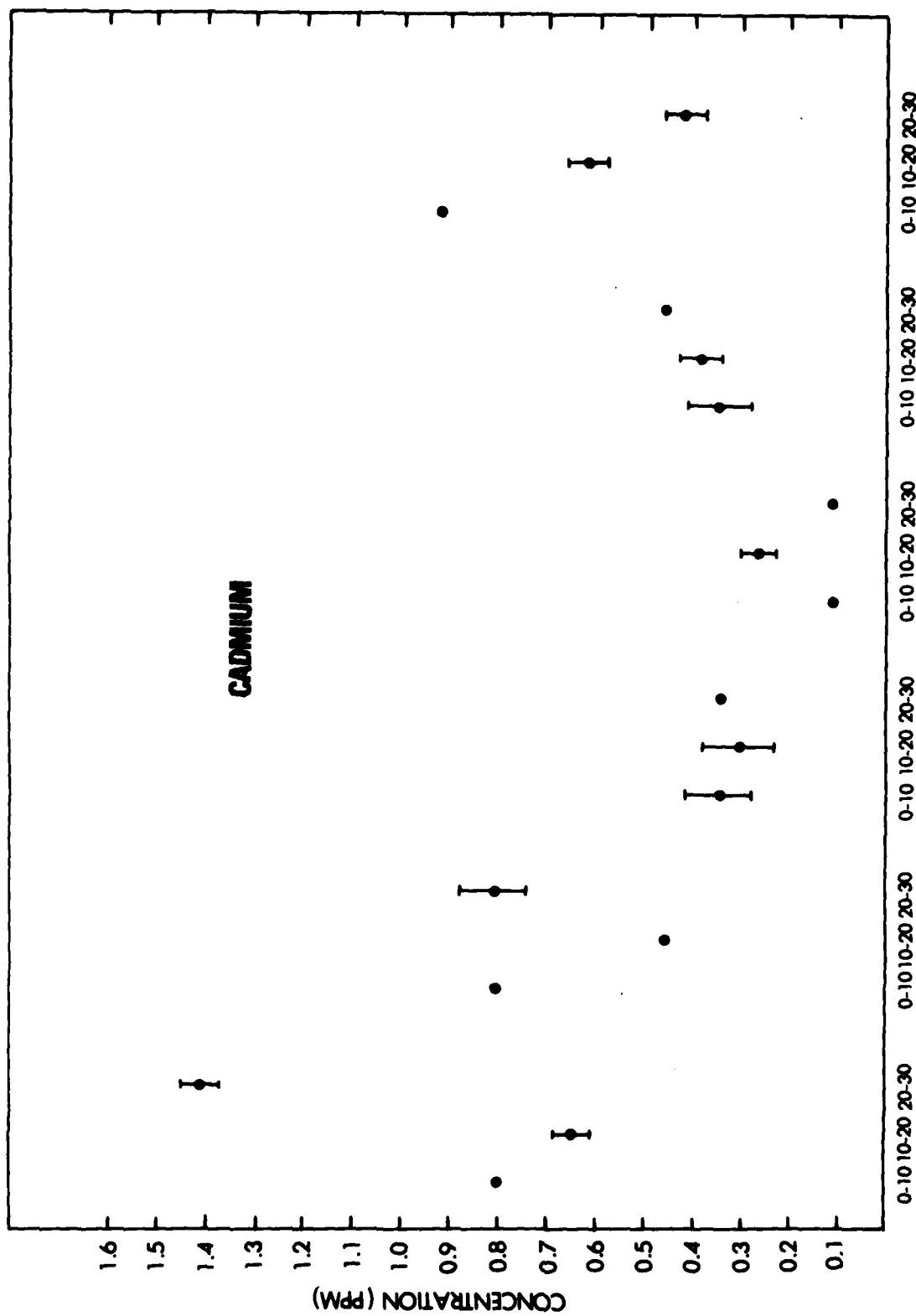


Figure 20A. Concentration of cadmium in ppm displayed as the mean of three replicate samples for each 10 cm depth \pm standard error



Figure 20B. Concentration of cadmium in ppm displayed as the mean of three replicate samples for each 10 cm depth

NICKEL

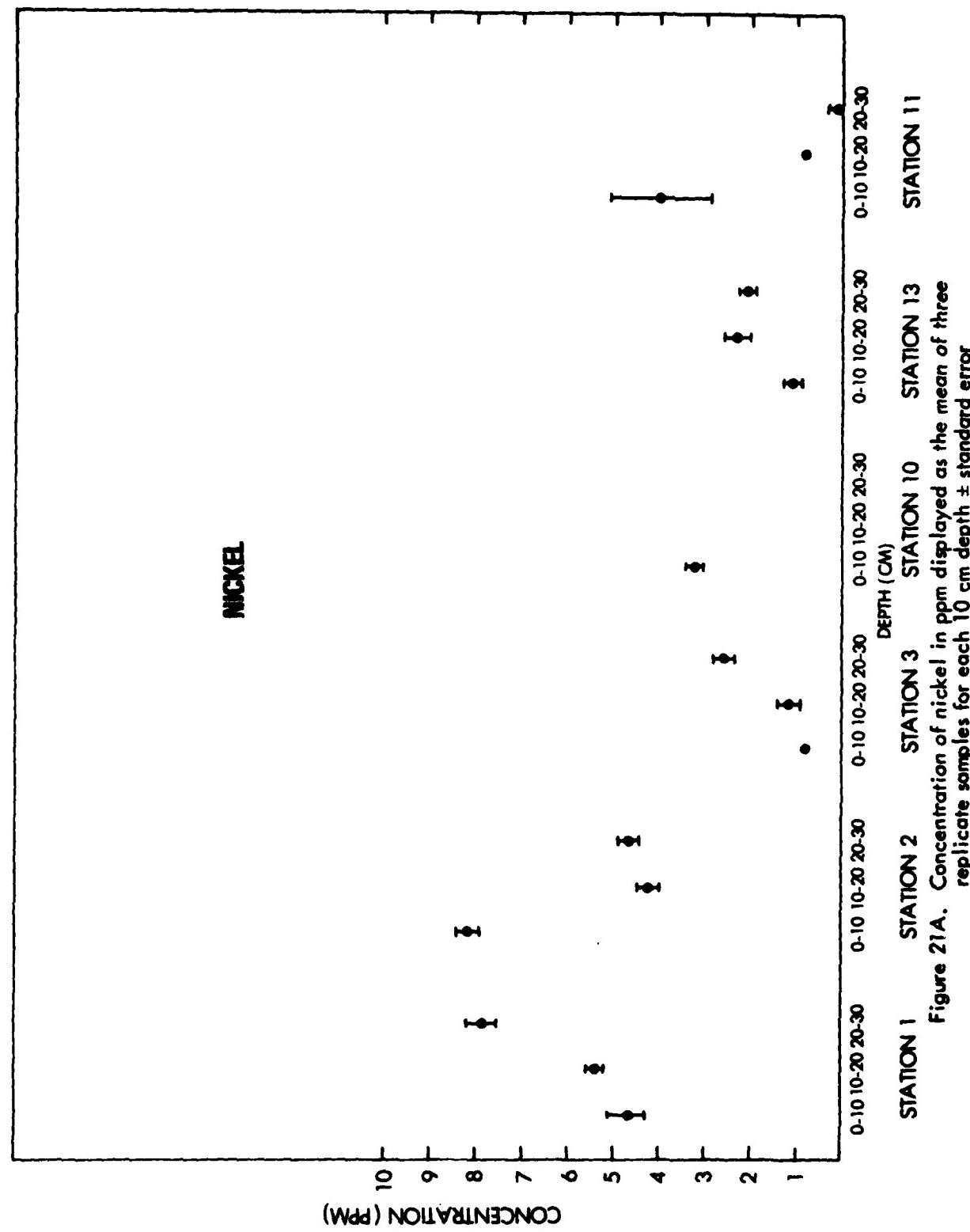


Figure 21A. Concentration of nickel in ppm displayed as the mean of three replicate samples for each 10 cm depth \pm standard error

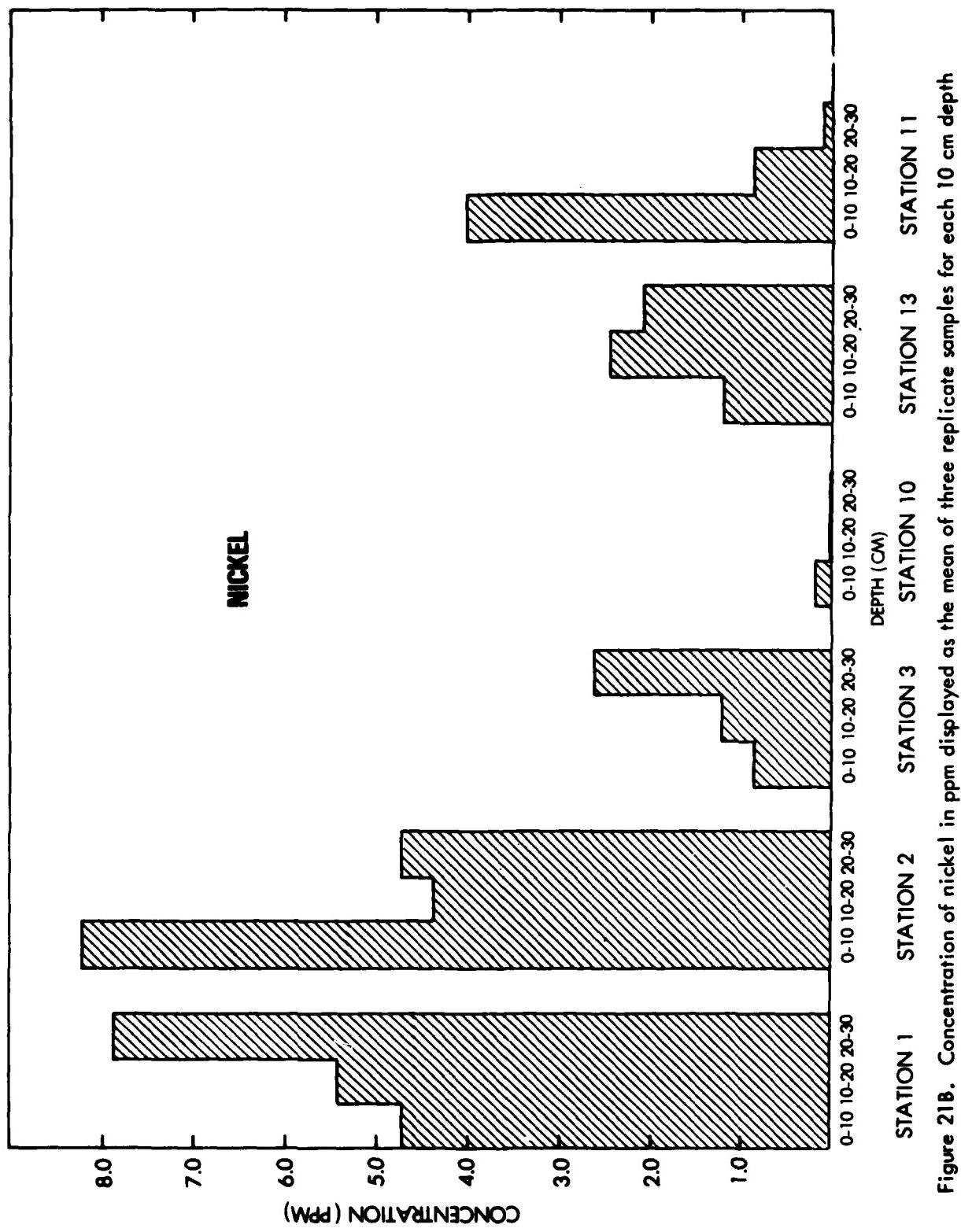


Figure 21B. Concentration of nickel in ppm displayed as the mean of three replicate samples for each 10 cm depth

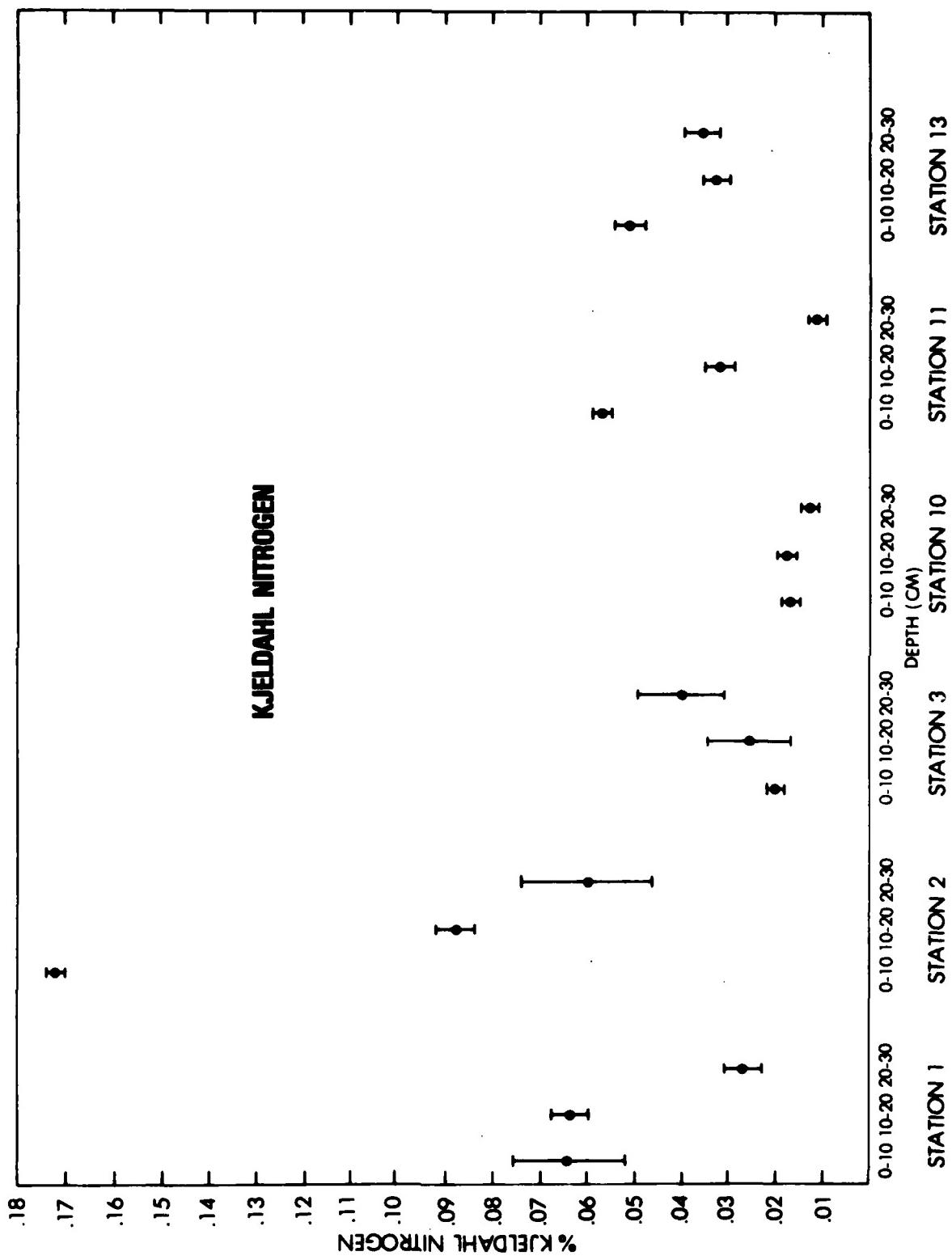


Figure 22A. Mean percent Kjeldahl nitrogen \pm standard error

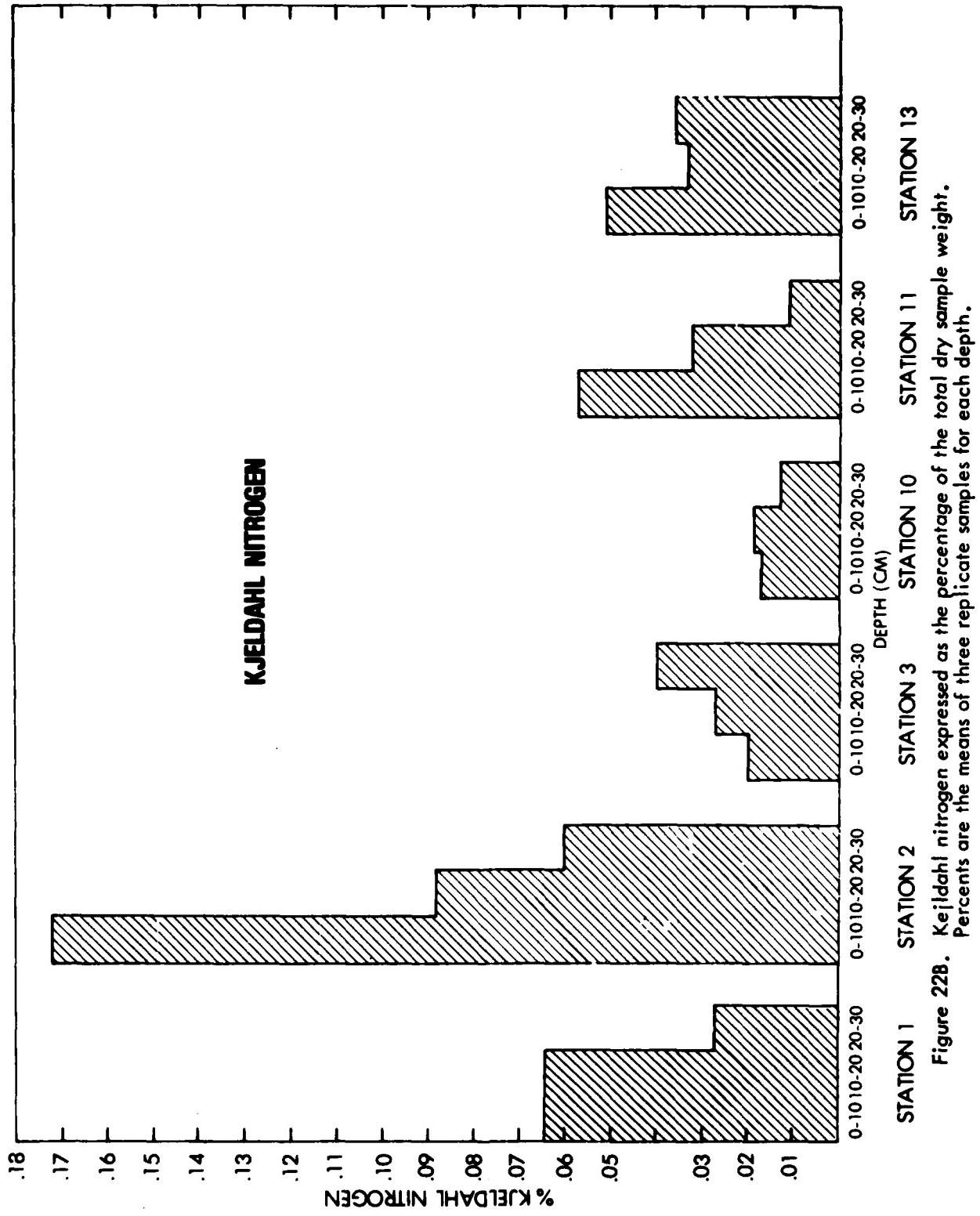


Figure 22B. Kjeldahl nitrogen expressed as the percentage of the total dry sample weight.
Percents are the means of three replicate samples for each depth.

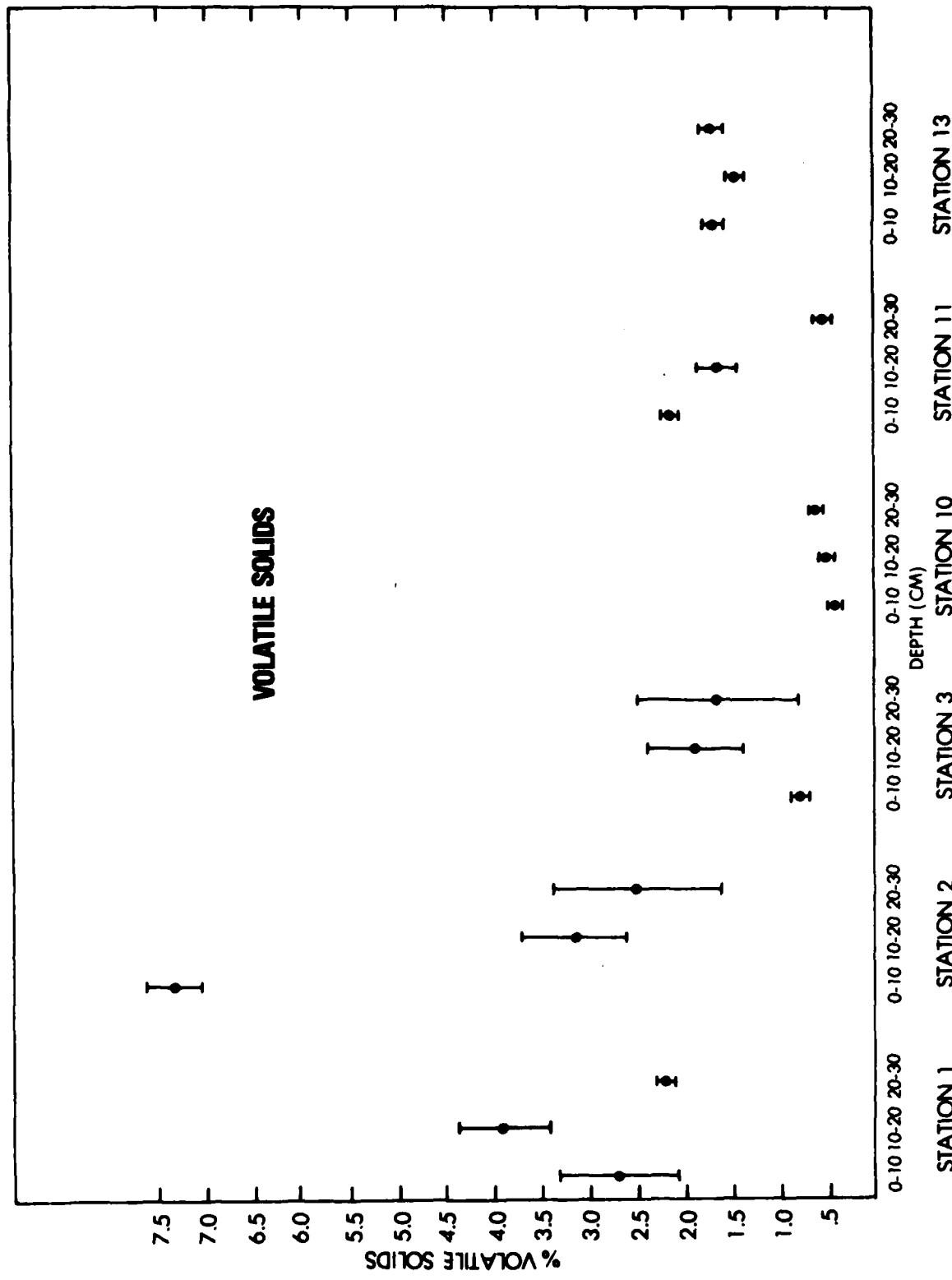


Figure 23A. Mean percent volatile solids + standard error

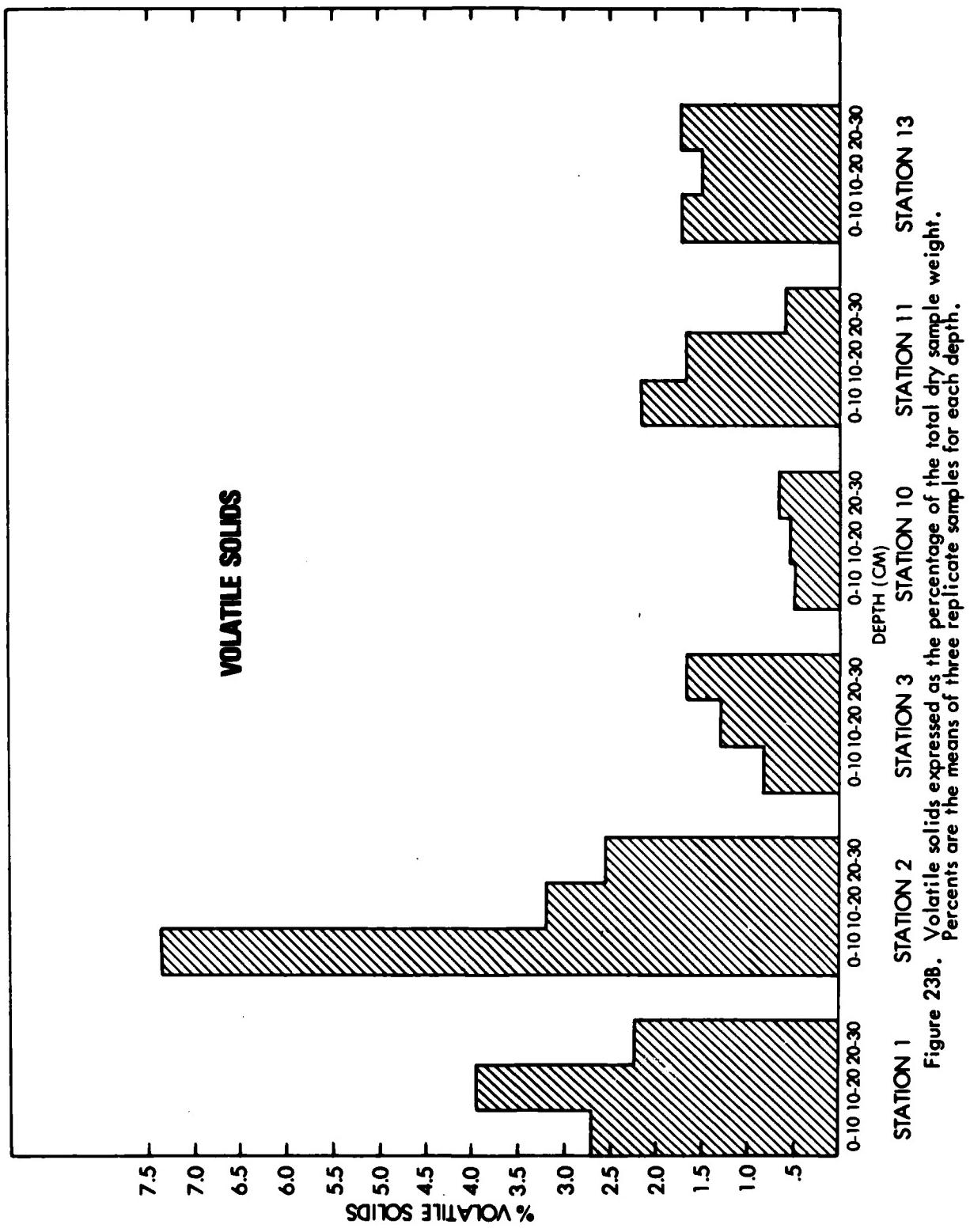


Figure 23B. Volatile solids expressed as the percentage of the total dry sample weight.
Percents are the means of three replicate samples for each depth.

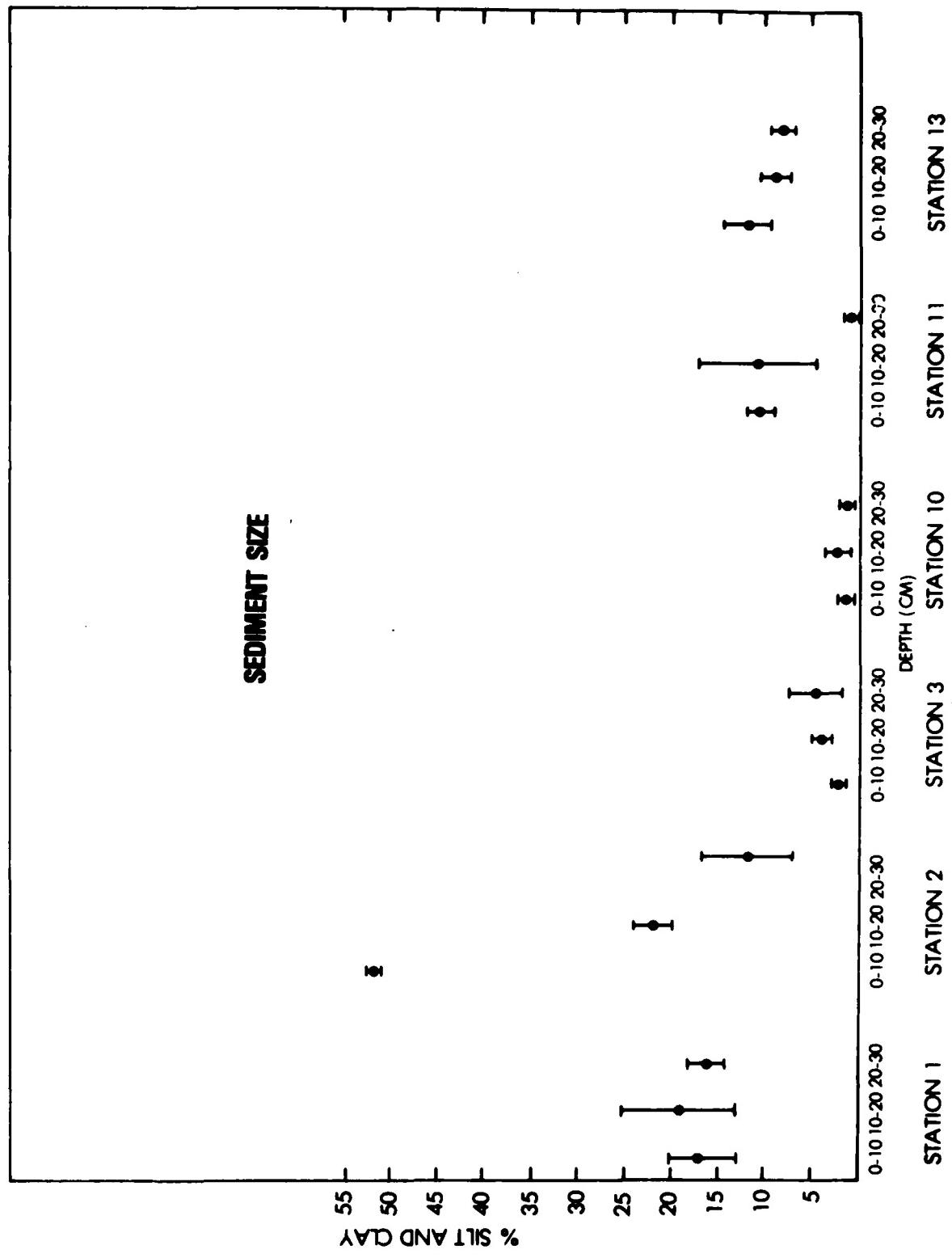


Figure 24A. Mean percent silt and clay (particles size 0.0625 mm and finer)
for each 10 cm depth + standard error

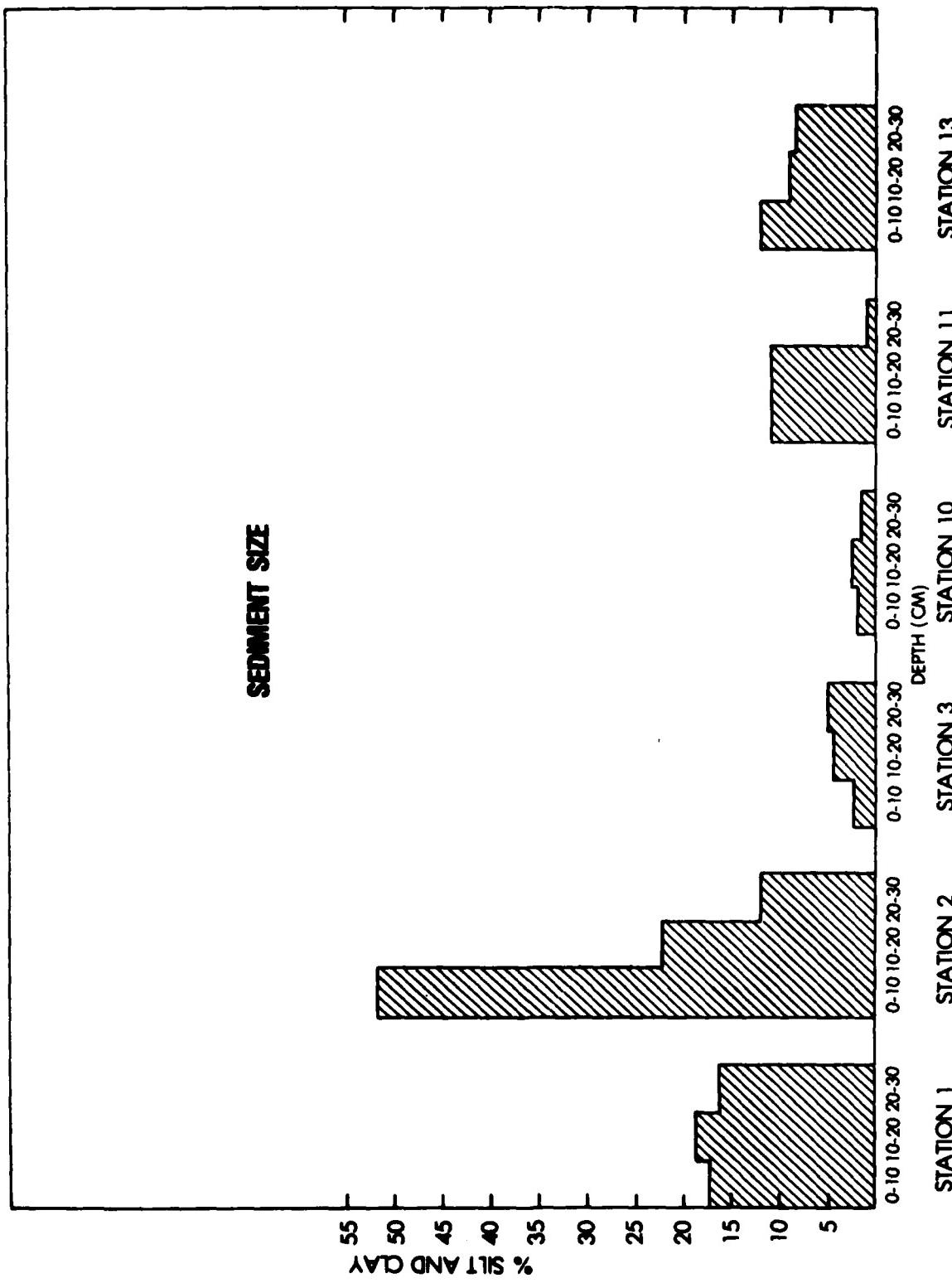


Figure 24B. Mean percent silt and clay (particles size 0.0625 mm and finer)
for each 10 cm depth

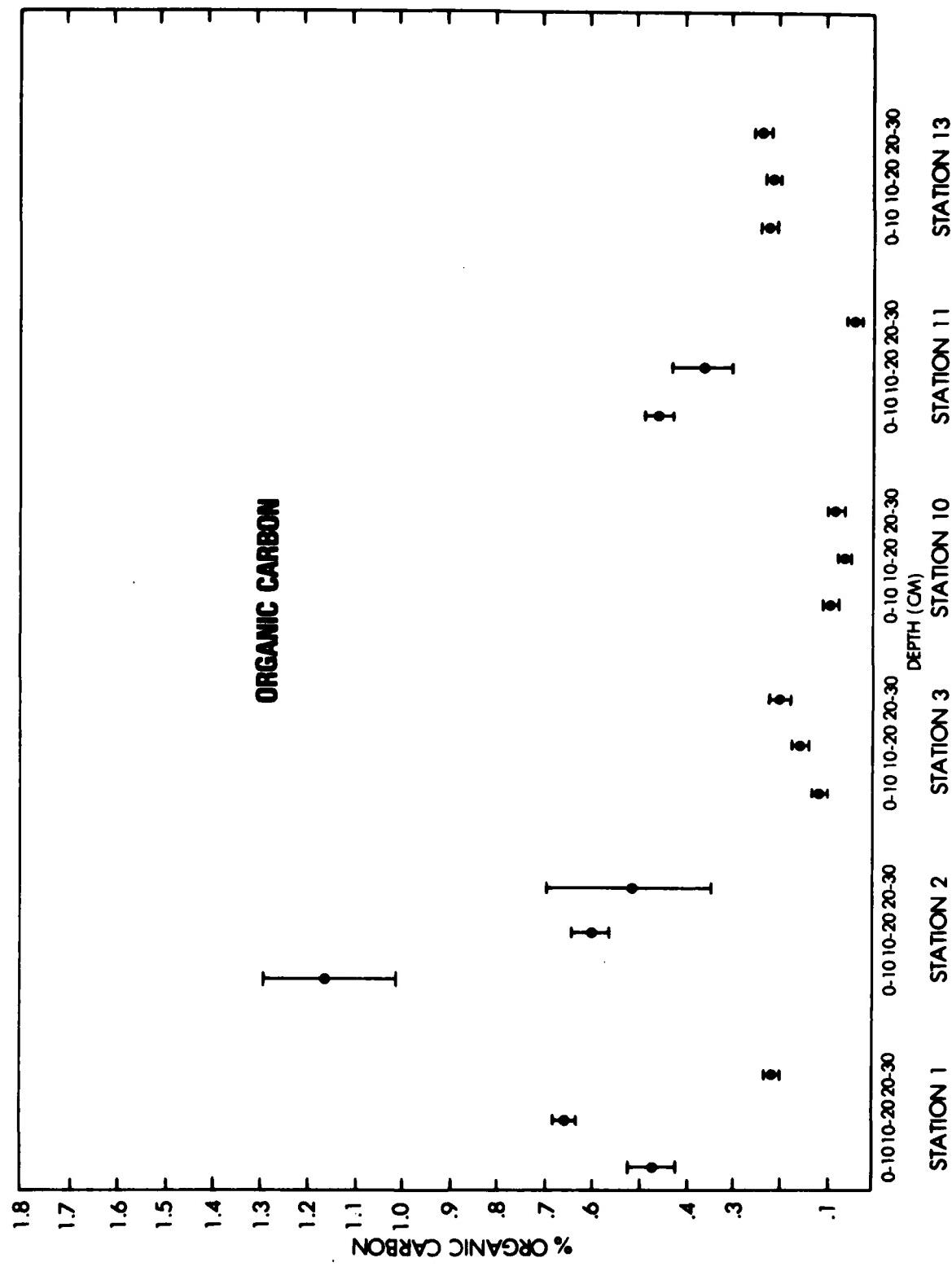


Figure 25A. Mean percent total organic carbon ± standard error

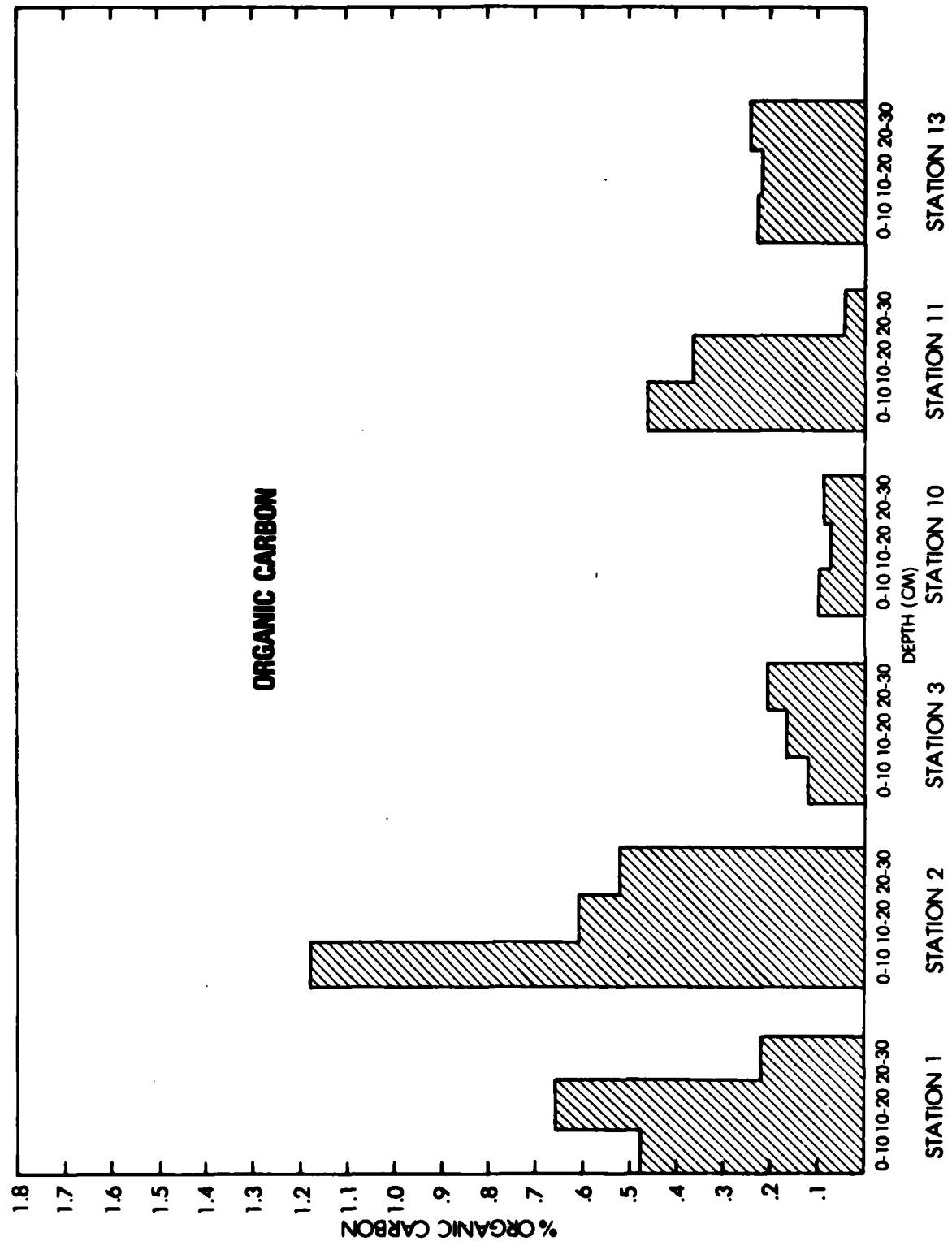


Figure 25B. Organic carbon expressed as the percent of the total dry sample weight.
Percents are the means of three replicate samples for each depth.

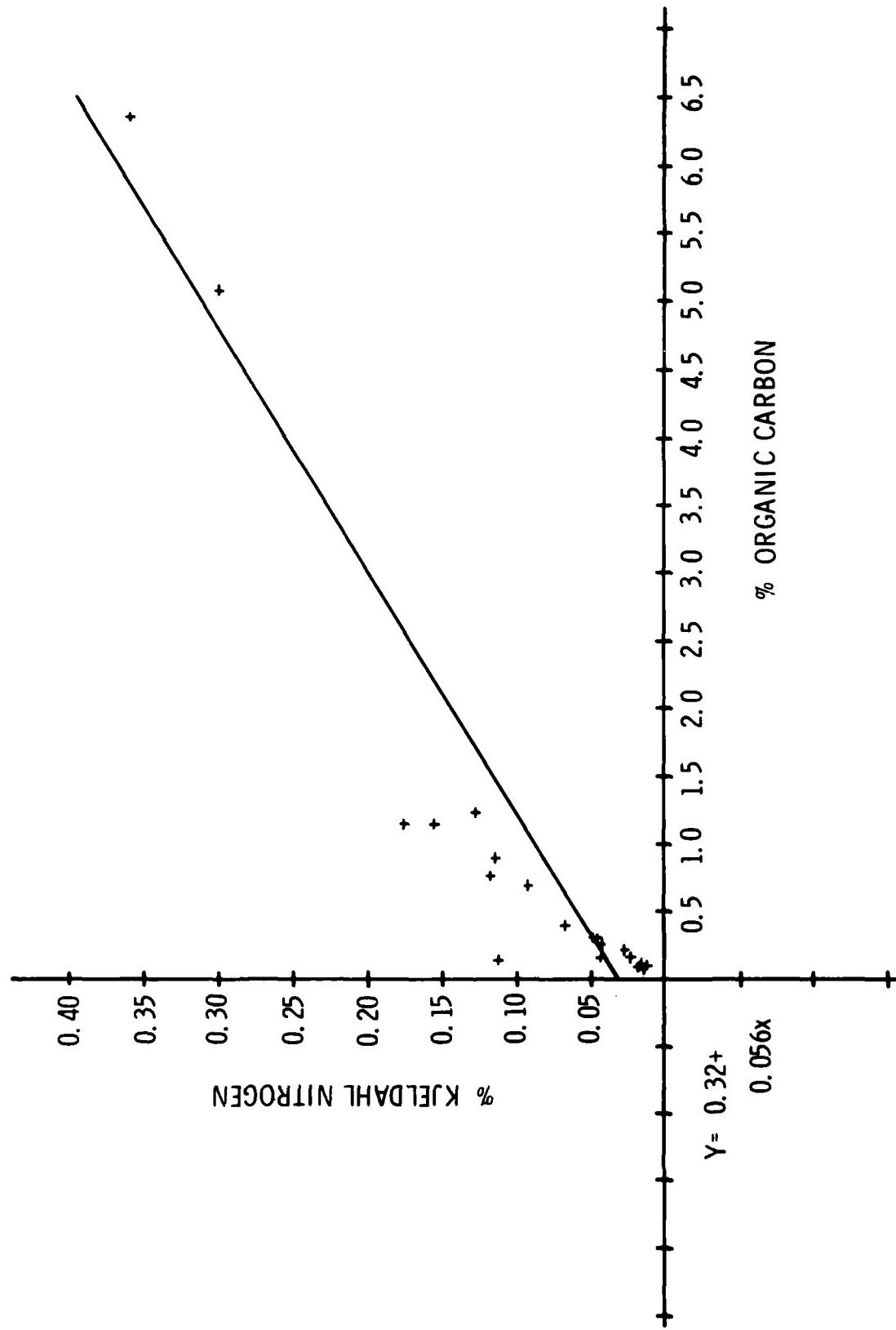


Figure 26A. Linear regressions of percent Kjeldahl nitrogen vs. percent organic carbon.
 $Y = a + bX$, where a is the Y intercept and b is the slope.

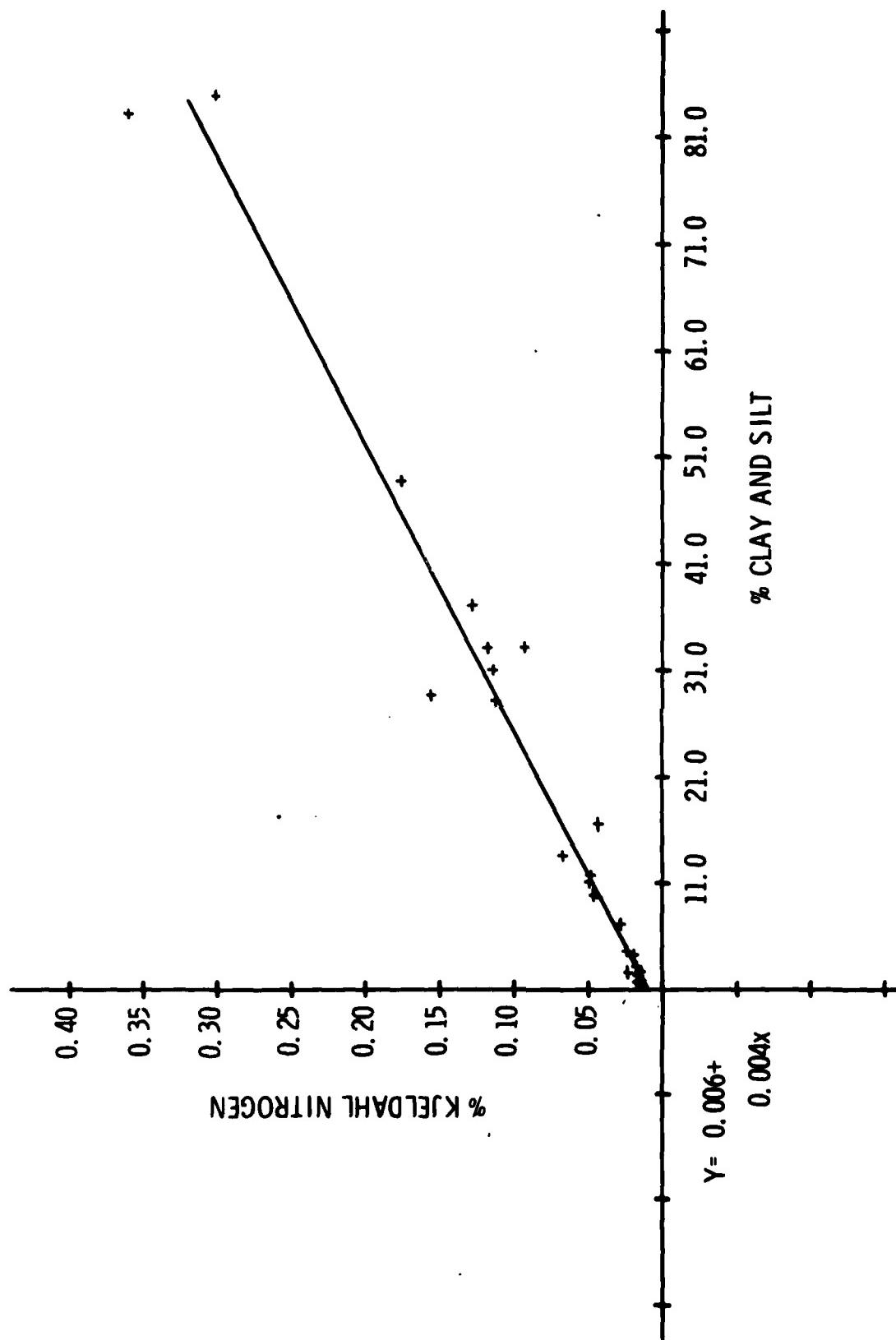


Figure 268. Linear regressions of percent Kjeldahl nitrogen vs. percent clay-silt.
 $y = a + bx$, where a is the Y intercept and b is the slope.

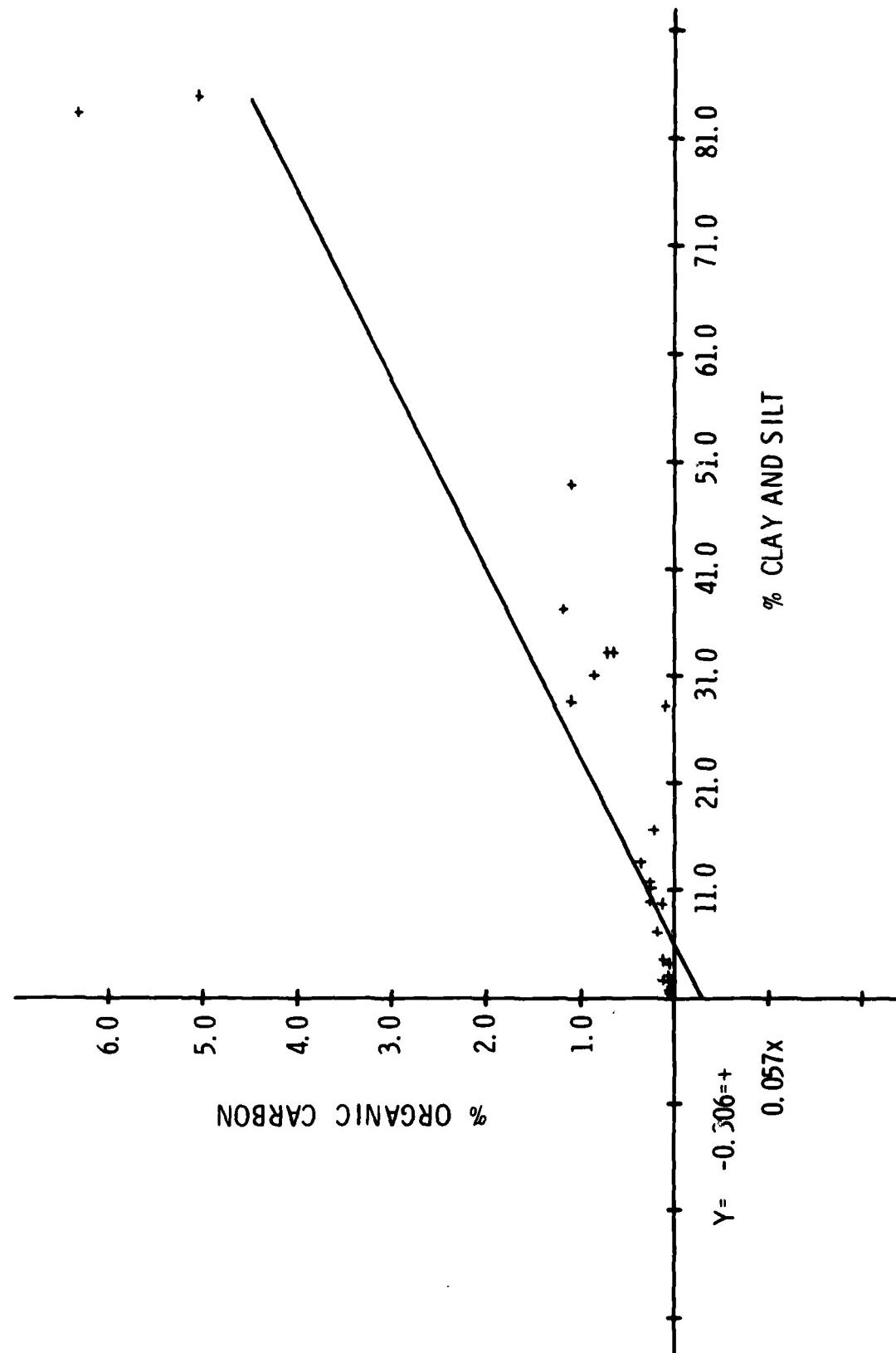


Figure 26C. Linear regressions of percent organic carbon vs. percent clay-silt.
 $Y = \alpha + bX$, where α is the Y intercept and b is the slope.

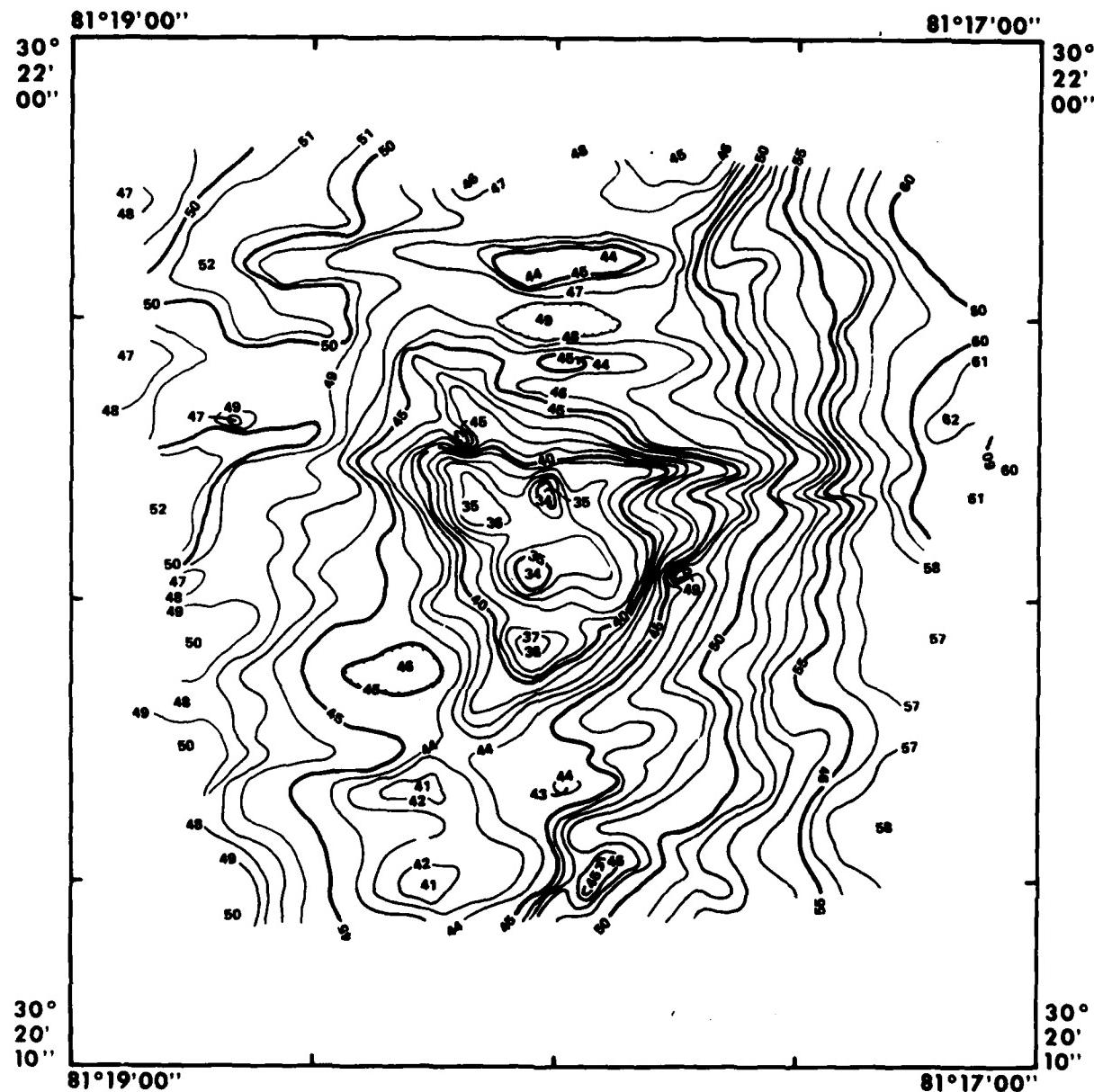


Figure 27. Bathymetric chart of disposal site at the time of the post-disposal survey (April 1978)

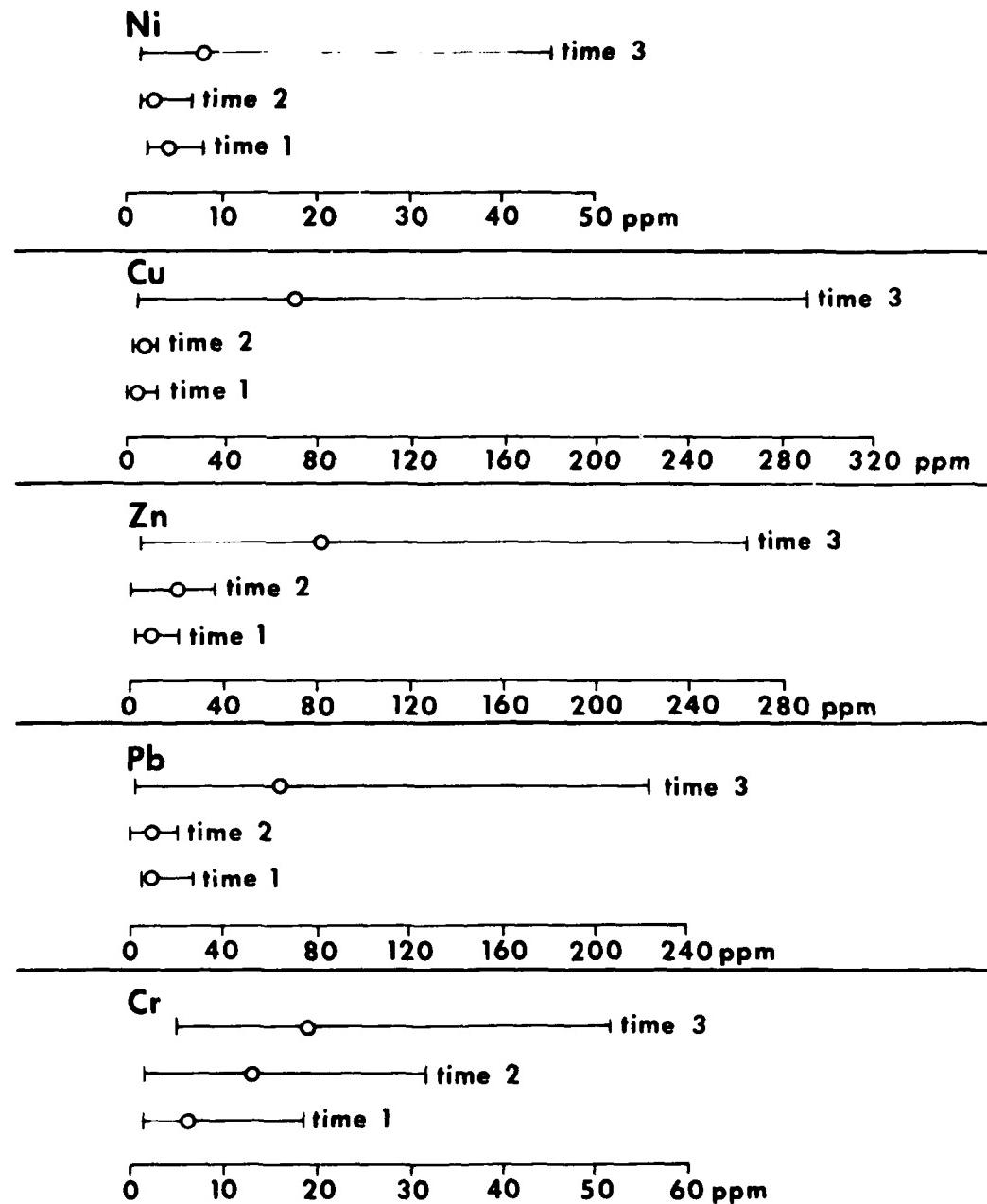


Figure 28. Mean concentrations (open circles) and ranges (solid lines) of nickel (Ni), copper (Cu), zinc (Zn), lead (Pb), and chromium (Cr) in sediments from grouped stations (1, 2, and 3) inside dredged material disposal site at Time 1 (February 1977), Time 2 (December 1977) and Time 3 (April 1978)

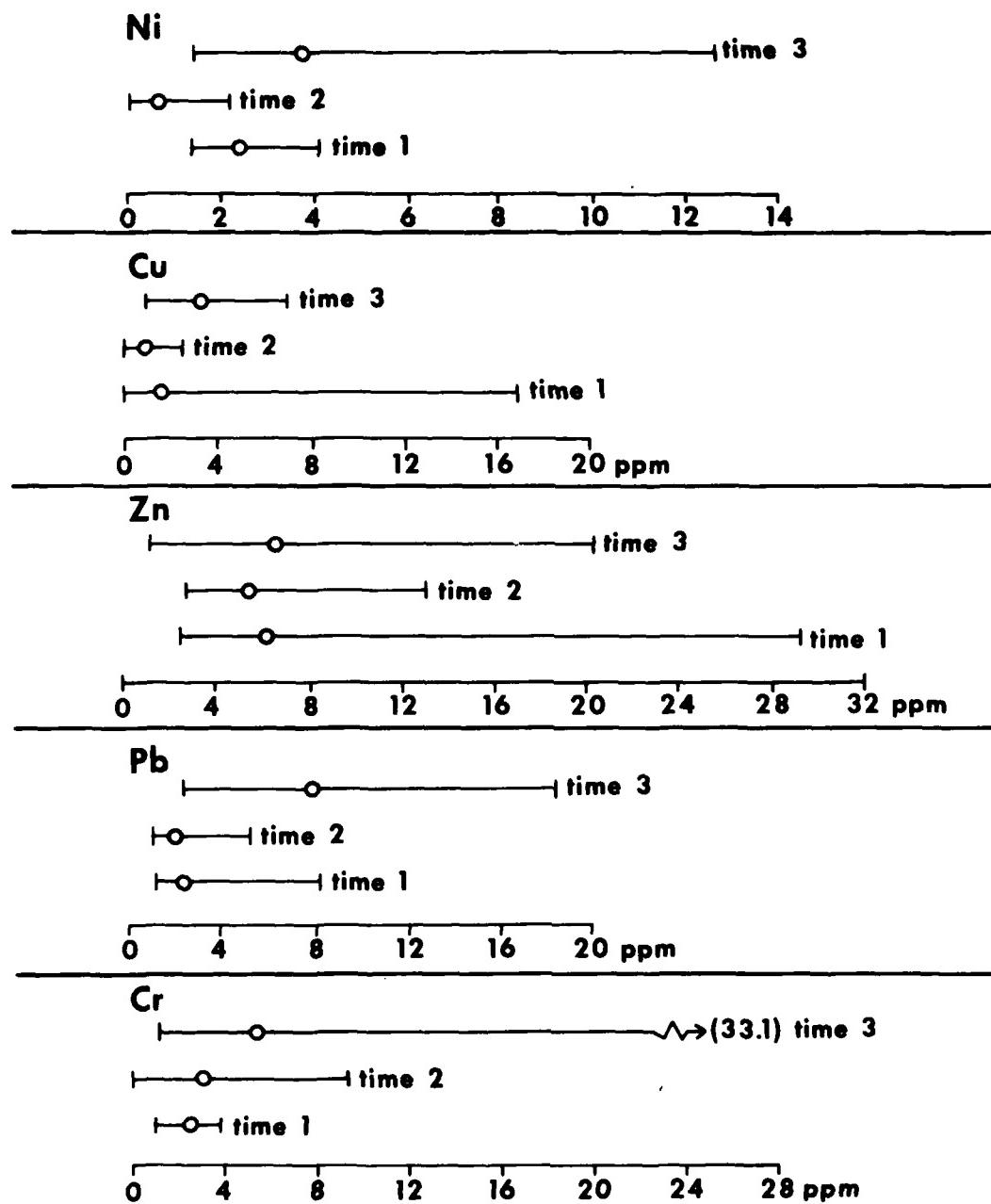


Figure 29. Mean concentrations (open circles) and ranges (solid lines of nickel (Ni), copper (Cu), zinc (Zn), lead (Pb), and chromium (Cr) in sediments from grouped stations (10, 11, and 13) outside dredged material disposal site at Time 1 (February 1977), Time 2 (December 1977), and Time 3 (April 1978)

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NORDA Technical Note 42	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
6 6 Ocean Dumping of Dredged Material at the Jacksonville Harbor Disposal Site: An Environmental Trend Assessment, February 1977 to April 1978.		9 9 TYPE OF REPORT & PERIOD COVERED Final rep't, 3 PEP, 1978
10 Brenda J. Little David K. Young		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Research and Development Activity NSTL Station, Mississippi 39529		10. PROGRAM ELEMENT PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		11. REPORT DATE Jun 1979
12. MONITORING AGENCY NAME & ADDRESS/IF different from Controlling Office		12. NUMBER OF PAGES 66
13. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		15. SECURITY CLASS (of this report) Unclassified
14. NORDA - TN-42		15a. DECLASSIFICATION DOWNGRADING SCHEDULE
16. SUPPLEMENTARY NOTES		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. KEY WORDS (Continue on reverse side if necessary and identify by block number) Dredged material, disposal site, sediment samples, elutriate tests, one-way analysis of variance, pre-disposal survey, during-disposal survey, post-disposal survey.		
19. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Biological and Chemical Oceanography Branch of the Naval Ocean Research and Development Activity conducted a three-phase study to assess the environmental effects of depositing 2,907,750 cubic yards of dredged material at the Jacksonville Harbor ocean disposal site designated for such purposes by the U. S. Environmental Protection Agency. Approximately 56% (1,637,000 cubic yards) of this material was dredged from the U. S. Naval Station, Mayport, Florida. The distribution of dredged material at the disposal site was found to be both vertically and horizontally heterogeneous.		

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Changes in bottom topography, coupled with significant increases of certain heavy metals (Ni, Cu, Pb, Zn, and Cr) within the disposal site, can be attributed to the accumulation of dredged material during the period of investigation. A standard elutriate test indicated that heavy metals were bound to the Mayport dredged material and could not be readily released to the water column during disposal operations.

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